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Biology and Illustrated Key for the Identification of Twenty Species of Economically Important Noctuid Pests

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Biology and Illustrated Key for the Identification of Twenty Species of Economically Important Noctuid Pests

A. D. Oliver and J. B. Chapin[1]

Introduction

This bulletin contains keys, figures, and plates for use in the identification of 20 species of noctuid caterpillars and moths of importance to Louisiana agriculture. According to Webster, a caterpillar is the elongated, wormlike larva of a butterfly or moth. A noctuid caterpillar, therefore, is the wormlike larva of moths in the family Noctuidae.

Noctuidae is the largest family in the order Lepidoptera, consisting of 2,500 to 2,800 species or about 30 percent of the Lepidoptera in North America. Most species are nocturnal, that is, active at night. Typical noctuid moths have a wingspan of 25 to 50 mm. The largest noctuid moth reported in the United States is the black witch, *Erebus odora* (L.), with a wingspan of about 12 cm. Some of the smallest have a wingspread of 12 to 17 mm. Typical larvae are 25 to 50 mm long.

Many of the most serious insect pests in the world belong to this family. Often referred to as worms, e.g., cutworms, armyworms, leafworms, earworms, and budworms, the larvae are annual pests of many crops grown in Louisiana.

These larvae develop through 6 or 7 instars (stages) over a period of about 30 to 50 days under optimum conditions. The time interval between any two instars is referred to as a stadium. When a caterpillar molts, it is in the next instar (stage) and developmental period or stadium. It is during the development of the last 2 or 3 instars that most food is consumed and crop injury occurs.

Because of the importance of noctuid caterpillars as crop pests in Louisiana, this bulletin was prepared as an aid to entomological consultants, farmers, and extension agents in making proper identification of 20 species of caterpillars which are responsible for much of the crop injury in the state. Users of the key should become familiar with the external anatomy of caterpillars (Fig. 1 A-B; Fig. 2 A-E) before attempting to identify them. Use of all figures and plates as indicated in the key to species will aid materially in making correct identifications.

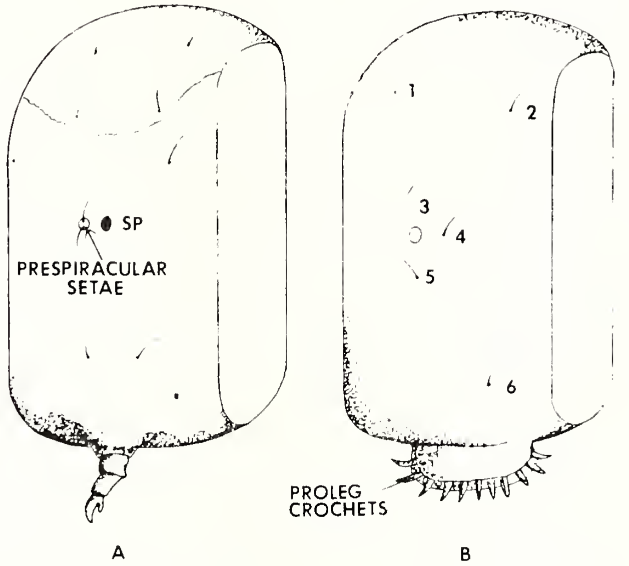

Fig. 1.—Characteristics used to place a larva in the family Noctuidae.
A.—Prothoracic segment with bisetose prespiracular tubercle.
B.—Abdominal segment with primary setae only; seta 4 behind and seta 5 below the spiracle. Proleg crochets are in a uniordinal, uniserial, longitudinal mesoseries.

Because many species resemble each other so closely, it will be difficult at times to make proper identification especially if host and habitat are not known. One cannot be too careful in ascertaining the time of year and exact location where a caterpillar was found, its host, the growth stage and part of the host fed upon, and the type of injury caused such as defoliation, stem or bud boring, etc. Some species are single-brooded; others have two or more broods a year. Some species are native to Louisiana; others migrate northward from more southern areas and usually do not overwinter here.

When monitoring an insect population in the field, one often collects several species (kinds) of worms which may be difficult to distinguish. Some may be

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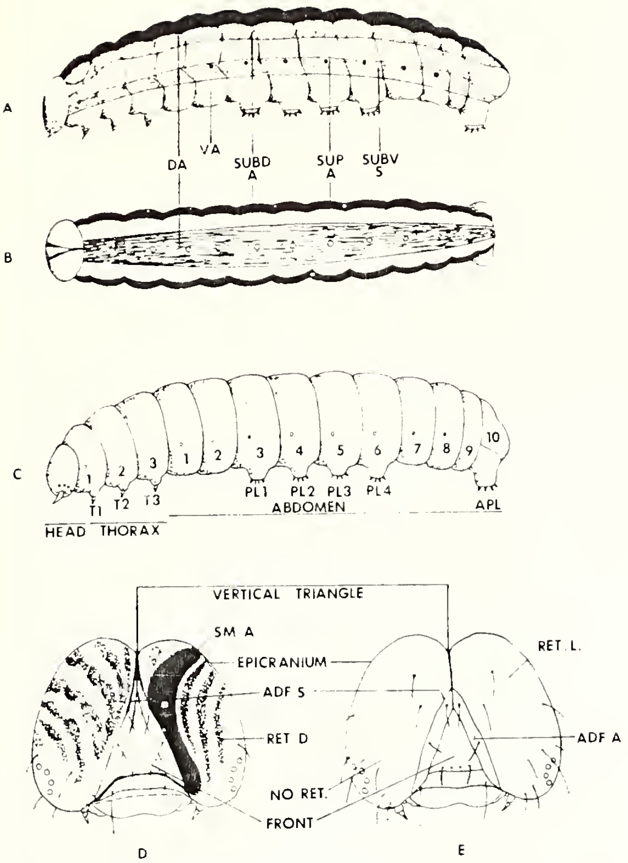

Fig. 2.—External anatomy of a noctuid caterpillar.
A. and B. A. Lateral view and B. dorsal view of typical caterpillar. DA, dorsal area; VA, ventral area; SUBD. A., subdorsal area; SUP. A., supraspiracular area; SUBV. S., subventral stripe.
C. Lateral view of caterpillar showing body segmentation; T1, prothorax; T2, mesothorax; T3, metathorax; PL1, first pair of abdominal prolegs; PL2, second pair of abdominal prolegs; PL3, third pair of abdominal prolegs; PL4, fourth pair of abdominal prolegs; APL, anal pair of prolegs.
D and E. Head capsules. SM.A., submedian arc; ADF.S., adfrontal suture; RET.D., reticulations, dark color; RET.L., reticulations, light color; ADF.A., adfrontal area; NO RET., no reticulations.

important pests; others may be incidental and present no problem. Need for proper identification, therefore, is a most important consideration in pest control.

Naturally, other important factors which influence pest control decisions are life cycle, seasonal history, seasonal distribution, and resurgence potential. The less experienced entomologist will face these problems often and may require advice from others.

Post-embryonic (after egg hatch) pigmentation of the body wall often varies among individuals in the population of a species. This variation may be attributed to genetics, host species, season of year, population density, and length of time since the last molt. Color characteristics aid in identification but must be used with caution.

Because of the remarkable similarities in anatomical characteristics of caterpillars, some people do not attempt to make an identification. It must be realized that the small degree of variation in structures can be used effectively in determining the species on hand.

Identifying Noctuid Larvae

A larva must be placed in the correct family before species identification can be made. The typical noctuid caterpillar body is without numerous secondary setae but has primary setae which are located in definite patterns or locations. It has more than one pair of abdominal prolegs. There are two setae in the Kappa group (prespiracular) on the prothorax in most species, but some exceptions exist such as the cotton leafworm which has one seta. The proleg-bearing segments have seta 4 behind and seta 5 below the spiracle on abdominal segments 1-6. The proleg crochets are arranged uniserially, uniordinally, and in a longitudinal mesoseries. These family characteristics are shown in Figs. 1-5.

The keys, figures, and illustrations in this paper are for use in the identification of some common noctuid caterpillars which are usually pests of crops in Louisiana. The information is not intended to include all species in the state but, instead, to provide brief information on identification, hosts, seasonal distribution, and type of injury caused by each species listed. *Spodoptera sunia* (Guenée) does not occur in Louisiana at this time but was included in case incipient infestations become established.

Figures are not drawn to scale but are furnished as aids in finding anatomical structures and characteristics used in making identifications. The keys and figures cannot be used to identify worms not listed in this paper.

Very young larvae of most species cannot be accurately identified with this or any other known key. It also must be realized that hosts, egg deposition characteristics, season, and larval habits are good aids in making identifications of larvae in any stage of development.

After using the key in making an identification, one should refer to the brief sections on summary description, hosts, seasonal history, and distribution given for each species. Species without accepted common names are indicated by an asterisk (*) in the descriptions which follow the larval key. A glossary of some common terms used in describing moths and caterpillars is provided at the end of the paper.

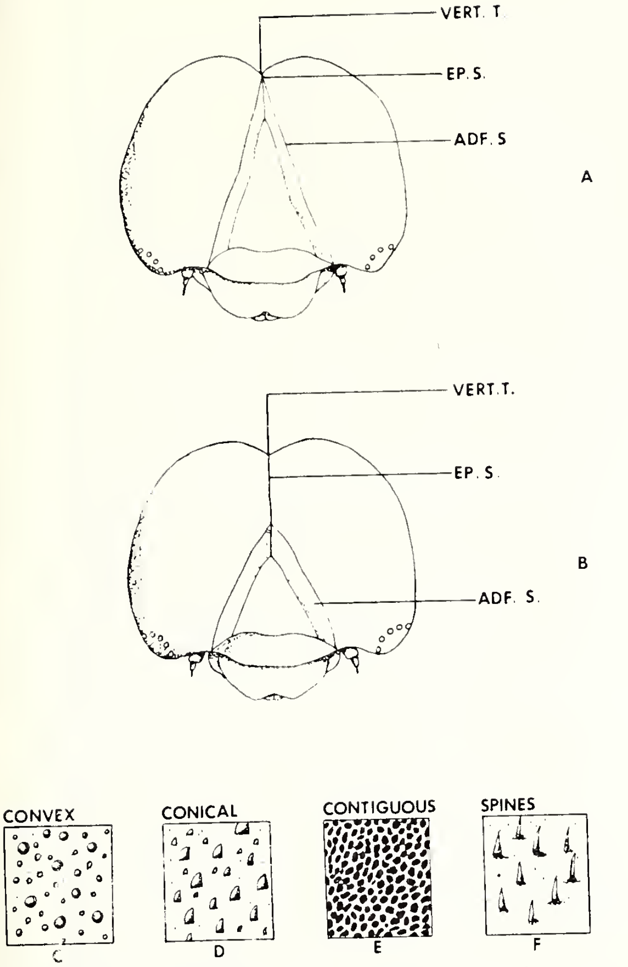

Fig. 3.—Head capsule and cuticle (skin) characteristics.
A.—Adfrontal sutures (ADF.S.) extending to near vertical triangle (VERT.T.) before reaching epicranial suture (EP.S.).
B.—Adfrontal sutures (ADF.S.) reaching epicranial suture (EP.S.) well below vertical triangle (VERT.T.).
C.—Skin granules convex.
D.—Skin granules bluntly conical and retrorse.
E.—Skin granules slightly elevated, contiguous, and appearing like stones in a wall.
F.—Skin spinose.

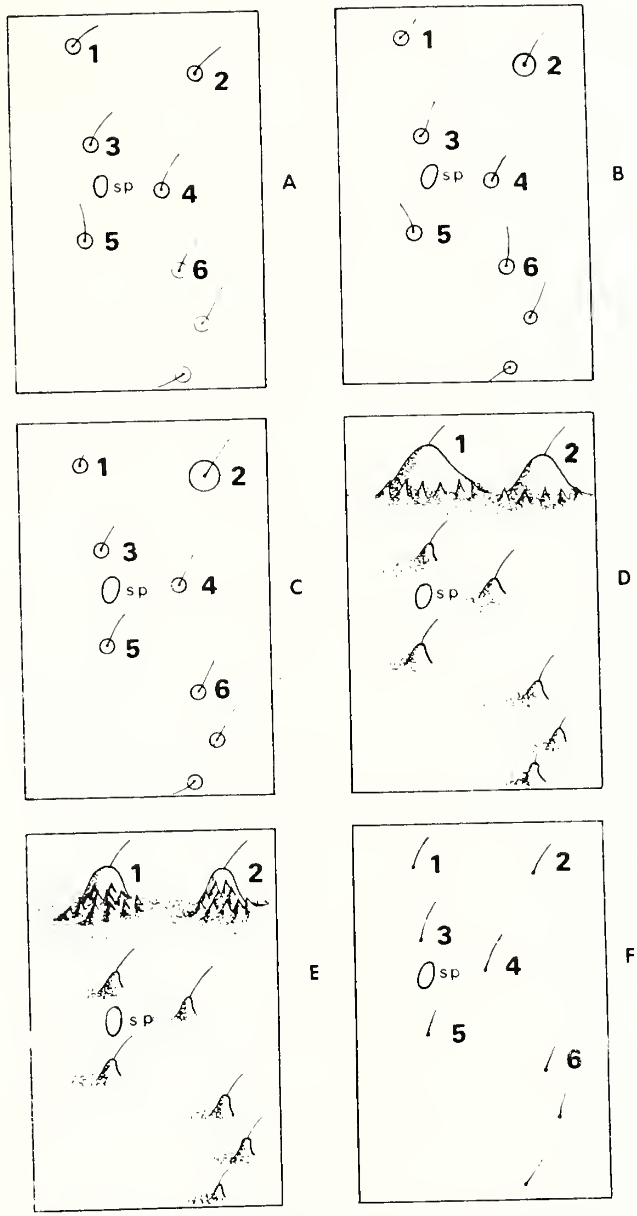

Fig. 4.—Chaetotaxal maps and tubercle size comparisons on first and second abdominal segments of some noctuid caterpillars.
A.—Setigerous tubercle 1 about equal in size to setigerous tubercle 2.
B.—Setigerous tubercle 1 about half the size of setigerous tubercle 2.
C.—Setigerous tubercle 1 about one-third the size of setigerous tubercle 2.
D.—Chalazas 1 and 2 without spinules extending toward apex.
E.—Chalazas 1 and 2 with spinules extending to about half the distance to apex.
F.—Minute setigerous tubercles.

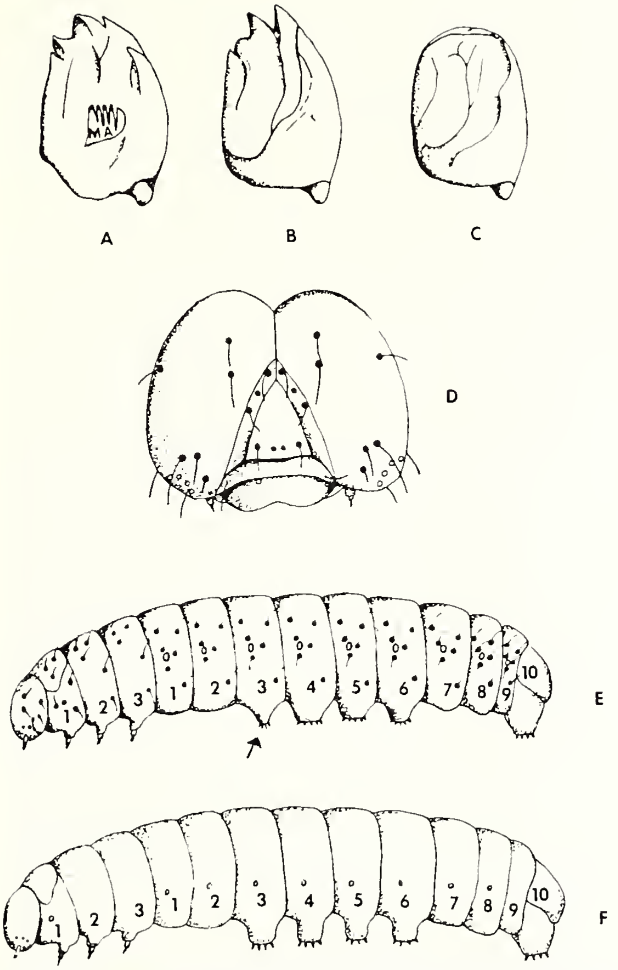

Fig. 5.—Mandible, head, tubercle, and proleg characteristics.
A.—Mandible with molar area (MA) on oral surface; with dentes.
B.—Mandible without molar area on oral surface; with dentes.
C.—Mandible without definite dentes (teeth).
D.—Head capsule with conspicuous large black tubercles (pinacula).
E.—First pair of abdominal prolegs (third abdominal segment) greatly reduced; large black tubercles on body.
F.—Abdominal prolegs about equal in size on abdominal segments 3, 4, 5, and 6.

The Larval Key

The dichotomous key presented herein for identification of 20 noctuid larval species was prepared using as few characteristics as deemed necessary to make proper identification. Naturally, many characteristics are possessed by any species which may aid in identification. In using the key, one examines a specimen to find its key characteristics and continues through the key until a description ends with the name of the insect. The group of species in the genus *Spodoptera* and especially those that were formerly in the genus *Prodenia* are difficult to identify. The intraspecific variation coupled with interspecific overlap in anatomical characteristics cause this problem especially with *Spodoptera latifascia* (Walker), *S. dolichos* (F.), and *S. eridania* (Cramer). As a result, the key to these species of larvae is not totally satisfactory. Identification of reared adults aided in separating these problem species.

Except for the fall armyworm, larvae in the genus *Spodoptera* are characterized by having minute setigerous tubercles and setae. Dark subdorsal markings of various shapes, a spot just above the spiracle of the first abdominal segment of some species, and several longitudinal stripes extending the length of the body are other general characteristics. The head capsule coloration also aids in separating some species. Levy and Habeck's (1973) descriptions of *Spodoptera sunia* (Guenée) and *S. latifascia* (Walker) and key to the *Spodoptera* larvae of the eastern United States was helpful in preparing the key to *Spodoptera* spp. in Louisiana.

Most specimens used in preparing the key were preserved in alcohol. The killing, fixing, and preserving process bleached some colors from the caterpillars. Green colors seldom remain, and as a result, species such as the green cloverworm and *Anicla infecta* (Ochsenheimer) become light yellow, tan, or white in color after preservation. Such changes must be considered when identifying preserved specimens.

Dichotomous Key to the Larvae of 20 Species of Important Noctuid Pests

1. Adfrontal sutures reaching epicranial suture near vertical triangle (Fig. 3 A) 2
Adfrontal sutures reaching epicranial suture well below vertical triangle (Fig. 3 B) 7

2. Cuticle (skin) smooth; dorsal yellow spot on each abdominal segment, anterior abdominal segments with yellow spots most conspicuous; center of spiracle black; conspicuous submedian arc on head capsule (Fig. 2 D) .... Variegated cutworm, *Peridroma saucia* (Hübner) (Plate I, Fig. A)
Cuticle (skin) granulose (Fig. 3 C-E) 3

3. Cuticular granules coarse, isolated, strongly convex or bluntly conical with smaller granules irregularly interspersed among them (Fig. 3 C-D) 4
Cuticular granules small, flat to slightly convex, and almost contiguous—like stones in a wall (Fig. 3 E) . 6

4. Cuticular granules bluntly conical, retrorse (Fig. 3 D); setigerous tubercle 1 of abdominal segments about half the size of setigerous tubercle 2 (Fig. 4 B); setigerous tubercle 4 as large as or larger than spiracle .... Granulate cutworm, *Feltia subterranea* (F.) (Plate I, Fig. C)
Cuticular granules strongly convex, not retrorse (Fig. 3 C) 5

5. Setigerous tubercles 1, 2, and 3 about same size (Fig. 4 A) .... Dingy cutworm, *Feltia ducens* Walker (Plate I, Fig. E)
Setigerous tubercle 1 about one-third the size of setigerous tubercle 2 (Fig. 4 C) .... Black cutworm, *Agrotis ipsilon* (Hufnagel) (Plate I, Fig. G)

6. Setigerous tubercle 1 of abdominal segments about half the size of setigerous tubercle 2 (Fig. 4 B); dorsum tinged with rusty red-brown .... Claybacked cutworm, *Agrotis gladiaria* Morrison (Plate II, Fig. A)
Setigerous tubercle 1 of abdominal segments about equal in size to setigerous tubercle 2 (Fig. 4 A); general color gray laterally to brown dorsally .... Palesided cutworm, *Agrotis malefida* Guenée (Plate II, Fig. C)

7. Cuticle conspicuously spinose (Fig. 3 F) 8
Cuticle appears to be smooth* 9

8. Tubercles (chalazas) 1 and 2 of abdominal segments 1, 2, and 8 bearing spinules to about half the distance to apex (Fig. 4 E); mandible with molar area (Fig. 5 A) .... Tobacco budworm, *Heliothis virescens* (F.) (Plate II, Fig. E)
Tubercles (chalazas) 1 and 2 of abdominal segments 1, 2, and 8 without spinules, but if present never reaching one-fourth the distance to apex (Fig. 4 D); mandible without molar area (Fig. 5 B) .... Cotton bollworm, *Heliothis zea* (Boddie) (Plate II, Fig. G)

9. Pinacula (tubercles) on head capsule and body conspicuously large and black with large setae (Fig. 5 D); body slender with pattern of longitudinal white stripes, prolegs on third abdominal segment about one-third the size of prolegs on fourth, fifth, and sixth abdominal segments (Fig. 5 E) .... Cotton leafworm, *Alabama argillacea* (Hübner) (Plate III, Fig. A)
Pinacula (tubercles) on head capsule not conspicuously large or black; prolegs on third abdominal segment absent or if present, not reduced (Fig. 5 F) 10

10. With three pair of abdominal prolegs; body a uniform green with irregular longitudinal white stripes (last instar without white stripes) .... Green cloverworm, *Plathypena scabra* (F.) (Plate III, Fig. C)
With two or four pair of abdominal prolegs 11

11. With only two pair of abdominal prolegs .... Loopers**
With four pair of abdominal prolegs 12

12. Body slender with seven definite longitudinal white stripes; conspicuous medium-sized setigerous tubercles; spiracles light brown with dark rim inside pale spiracular line; epicranium with faint reticulations; venter unmarked green to brown .... Velvetbean caterpillar, *Anticarsia gemmatalis* Hübner (Plate III, Fig. E)
Body without seven definite longitudinal white stripes 13

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* Cuticle of fall armyworm densely clothed with micro-granules which are seen only with high magnification.

** Loopers not included in this publication.

13. Mandibles without conspicuous dentes (teeth) (Fig. 5 C) 14
Mandible with definite dentes (Fig. 5 A-B) 15

14. Dorsal setigerous tubercles minute; subdorsal markings obliterated; a conspicuous broad longitudinal white stripe laterally; spiracles white to light yellow with dark rim .... A grasswonn, *Anicla infecta* (Ochsenheimer)*** (Plate III, Fig. G)
Dorsal setigerous tubercles medium-sized; dark linear subdorsal markings conspicuous; spiracles black; a diagonal dark band on lateral aspect of abdominal prolegs .... Armyworm, *Pseudaletia unipuncta* (Haworth) (Plate IV, Fig. A)

15. Dorsal setigerous tubercles (pinacula) large, conspicuous, as large as or larger than spiracle; cuticle clothed with dense micro-granules; spiracles light brown; head conspicuously reticulated .... Fall armyworm, *Spodoptera frugiperda* (J. E. Smith) (Plate IV, Fig. C)
Dorsal setigerous tubercles minute, inconspicuous, no more than half the size of spiracle (Fig. 4 F); abdominal segments with variously-shaped dark subdorsal markings; cuticle smooth; mid-dorsal line usually not continuous 16

16. Setigerous tubercles minute; abdominal segments with definite subdorsal markings bordered ventrally by a longitudinal white stripe; dark spot usually in supraspiracular area of mesothorax; cuticle shiny smooth; head dark brown with conspicuous reticulations and light adfrontals .... Beet armyworm, *Spodoptera exigua* (Hübner) (Plate IV, Fig. E)
Setigerous tubercles small; no dark spot in supraspiracular area of mesothorax, but usually one on the first abdominal segment 17

17. Abdominal segments with prominent yellow-brown subspiracular line usually interrupted by dark spot on the first abdominal segment; an oval white mark as large as or larger than spiracles within dark area just posterior and slightly dorsal to spiracle on abdominal segments 2 to 6; head capsule light brown with very faint reticulations .... Southern armyworm, *Spodoptera eridania* (Cramer) (Plate IV, Fig. G)
Abdominal segments without prominent yellow-brown subspiracular line or if line is present, it passes ventral to dark spot on first abdominal segment 18

18. Dark semicircular or triangular subdorsal markings with conspicuous white mark near mesal point of triangle, an oval white mark within dark area posterior to spiracle on abdominal segments 1 to 6; venter mottled with flecks of pink, white, and yellow; head brown with lighter reticulations. (Species presently does not occur in Louisiana) .... *Spodoptera sunia* (Guenée)*** (Plate V, Fig. A)
Dark subdorsal markings without conspicuous white mark near mesal point; no oval white mark in definite dark area posterior to spiracle on abdominal segments 1 to 6 19

19. Dark, triangular, subdorsal markings on mesothorax; dark subdorsal markings on abdominal segments with irregular narrow white line passing through; numerous interrupted narrow white lines between spiracles and subdorsum; head capsule dark brown to black with conspicuously white adfrontals; lateral epicranium lighter brown .... Yellowstriped armyworm, *Spodoptera ornithogalli* (Guenée) (Plate V, Fig. C)
Dark subdorsal markings on mesothorax more or less semicircular or rectangular; dark subdorsal markings on abdominal segments without white lines passing through; numerous more or less small white spots between spiracle and subdorsum; head brown to dark brown with lighter reticulations 20

20. Dark subdorsal markings on mesothorax more or less semicircular and usually much smaller than subdorsal markings on eighth abdominal segment; head capsule more or less uniformly brown with lighter reticulations; adfrontals tan .... *Spodoptera latifascia* (Walker)*** (Plate V, Fig. E)
Dark subdorsal markings on mesothorax more or less triangular or trapezoidal in shape and about same size as marks on eighth abdominal segment; head brown to fuscous with lighter reticulations and white adfrontals .... *Spodoptera dolichos* (F.)*** (Plate V, Fig. G)

*** No accepted common name for these species.

Identifying Noctuid Adults

Moths are usually heavy-bodied, medium-sized, and dull colored. Ocelli are present, and the labial palpi extend to or beyond the middle of the front. In the front wing the cubitus vein appears to be four-branched because vein M_2 arises closer to vein M_3 than to vein M_1. In the hind wing, the frenulum is present, the subcosta and radius veins fuse for a short distance just beyond the base of the wing and separate well before the middle of the discal cell, the cubitus vein may appear to be three- or four-branched because vein M_2 may be absent or present, and there are two anal veins (Fig. 6 A).

Arctiidae and Agaristidae are families similar to Noctuidae in wing venation, but most species are brightly colored. Several other families may be mistaken for noctuids but can be separated by certain characteristics—Liparidae lack ocelli, Lasiocampidae lack a frenulum, Pyralidae have three anal veins in the hind wing, and the cubitus vein in the front wings of Geometridae and Notodontidae appears three-branched.

Adults of the caterpillar species covered in this paper were described for use by those who may wish to collect them in light traps. A difficulty in collecting is that they must be separated from all other moths, some of which may be similar in appearance. Forbes (1954) reported that the family Noctuidae was extremely homogeneous and difficult to subdivide in either a natural or convenient way. No keys are given to these species for these two reasons. The wing pattern description and diagram follows that of Forbes (1954). The lines from the base to the apex of the wing are basal, antemedial, median, postmedial, subterminal, and terminal. The orbicular and reniform spots are at the middle and end of the discal cell, respectively, and the elongate claviform spot is located behind the orbicular spot. The basal dash extends from the base of the wing to the antemedial line, the median dash lies between the antemedial and postmedial lines, and the anal dash extends from the postmedial through the subterminal lines (Fig. 6 B). If moths are not handled carefully, the scales forming the wing patterns will be removed, and it will be necessary to use characteristics of the genitalia for moth identification.

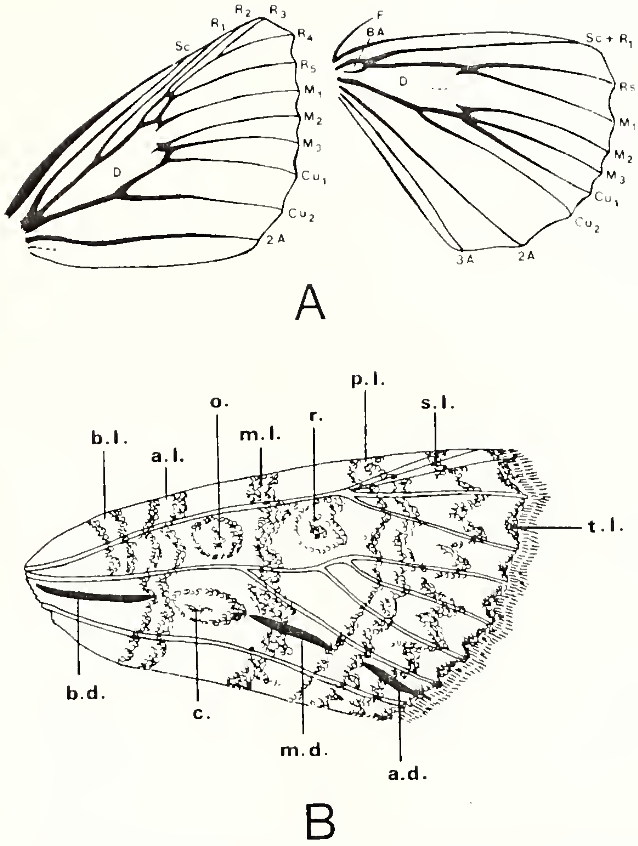

Fig. 6.—Wing characteristics used to identify noctuid moths.
A.—Wing venation of a typical moth. BA, basal areole; D, discal cell; F, frenulum. Longitudinal wing veins: Sc, subcosta; R_1 to R_5, branches of the radius; Rs, radial sector; M_1 to M_3, branches of the media; Cu_1 and Cu_2, branches of the cubitus; 2A and 3A, 2nd and 3rd anal veins.
B.—Wing pattern of a typical moth. b.l., basal line; a.l., antemedial line; m.l., median line; p.l., postmedial line; s.l., subterminal line; t.l., terminal line; o., orbicular spot; r., reniform spot; c., claviform spot; b.d., basal dash; m.d., median dash; a.d., anal dash.

Summary Descriptions, Distributions, Hosts, and Seasonal Histories

Variegated cutworm, *Peridroma saucia* (Hübner)
(Plate I, Figs. A and B)

Summary description of larva: Adfrontal sutures almost reaching the vertical triangle; reticulations of head fuscous or ferruginous; coloring may be limited to submedian area and mesal to ocellar region; submedian arcs distinct. Skin smooth (unlike other cutworms discussed in this paper) and with setigerous tubercles minute. A series of yellow circular spots down the back (mid-dorsum) but most pronounced on anterior abdominal segments. Spiracles entirely black or with center brown.

Summary description of adult: Male antennae narrowly serrate basally, apparently filiform distally; female antennae, apparently filiform. Front wing with lines from basal to postmedial marked in black on the costa, often fading posteriorly; reniform spot large, kidney-shaped; orbicular spot nearly round, both narrowly outlined with black. Color variable—brown or

reddish-brown with spots similarly colored, or orbicular spot lighter; or blackish anteriorly and clay-colored posteriorly with spots blackish; or brown, paler along the costa and subterminally with reniform spot darker and orbicular spot often lighter. Hind wing dirty white, veins and margins darker.

Distribution: This cutworm is distributed throughout Louisiana.

Hosts: The variegated cutworm has a wide range of hosts. High populations build up in the winter legume crops such as clover, winter peas, and vetch. Infestations have been sufficient in parts of the Red River Valley to cause stand loss in seedling cotton in past years. Larvae may feed day or night and rest on soil surfaces or on host plants.

Seasonal history: Adults of the variegated cutworms are active most of the year in Louisiana, although more have been collected in late spring. Four to five generations occur annually in the state with highest larval populations appearing in April and May. The winter is passed primarily as pupae.

Granulate cutworm, *Feltia subterranea* (F.)

(Plate I, Figs. C and D)

Summary description of larva: Adfrontal sutures almost reaching vertical triangle; head capsule light brown with submedian arcs darker brown; brown reticulations ventral to submedian arcs. Cuticle granulose; granules isolated, bluntly conical, and project in retrorse (projecting slightly posteriorly). Setigerous tubercle 1 about half the size of setigerous tubercle 2. Spiracles black with brown near center. Dorsal area of body flecked with irregular dark brown pigmentation. General color of larva gray to dusty but flecked ventrally with white.

Summary description of adult: Recognized by the black bar between the usually pale orbicular and reniform spots. Antennae of male narrowly pectinate basally, apparently filiform distally; of female, apparently filiform. Forewing of male beige, shaded with black, darker subapically along the costa and at the base; lines usually indistinct; claviform spot elongate or absent. Forewing of female blackish usually with a pale area behind the costa extending to the orbicular spot and an irregular pale subapical band. Hind wing off-white, veins and margin sometimes pale brown.

Distribution: The granulate cutworm may be found throughout Louisiana. It is most abundant in the more southern areas and is one of the most important cutworm species in Louisiana, ranking first among the cutworms as a pest of many vegetable crops.

Hosts: Granulate cutworms feed on a wide range of plants, especially legumes and vegetables. Some years this insect is responsible for stand loss in tomato and pepper fields. Larvae feed by cutting off seedlings near the soil surface and by climbing and feeding on foliage and terminals. They usually hide during the day beneath clods of soil and field debris.

Seasonal history: As many as four to six generations occur annually in Louisiana. Although larvae are often found during winter months, they overwinter primarily as pupae in the soil. There are six to seven larval instars which require 35 to 50 days for development. Time required from egg to adult is about 65 days. Adults have been collected in all seasons of the year.

Dingy cutworm, *Feltia ducens* Walker

(Plate I, Figs. E and F)

Summary description of larva: The head characteristics are very similar to the granulate cutworm. Body characterized by granulose cuticle, with larger granules conspicuously convex and small granules interspersed among larger ones, and setigerous tubercles 1 and 2 of equal size. Dorsum ferruginous to gray in color, usually with a dark V-shaped marking on the posterior dorsum of each abdominal segment; a broad, pale central area contrasting with darker area along supraspiracular area, especially on anterior half of segments.

Summary description of adult: Antennae of male narrowly pectinate basally, apparently filiform distally; of female, apparently filiform. Front wing with costal, subterminal, and posterior areas light gray-brown frosted with white; median and terminal areas dark gray-brown; white fragments of basal and antemedial lines visible below the discal cell; veins finely black with whitish streaks on each side, very prominent above and below the cell; postmedial and terminal areas with dark brown wedges between the veins; orbicular spot V-shaped, open to costa, and both it and reniform spot partly filled with dark scales; claviform spot elongate, extending almost opposite reniform. Hind wing dirty white, darker along veins and margins, or sometimes dusted with brown in females.

Adults of this species may be confused with specimens of *Agrotis gladiaria* Morrison. However, the male antennae are broadly pectinate, and the orbicular spot is round or elongate and sometimes reduced in the claybacked cutworm. The dingy cutworm moth also resembles *F. herilis* (Grote), a few specimens of which have been collected in Baton Rouge and Franklin in October and November.

Distribution: This species is widely distributed in North America. In Louisiana, it is most likely to be found in the most northern parishes.

Hosts: The dingy cutworm is most often found in legumes, especially alfalfa in northwest Louisiana.

Seasonal history: There is one generation per year of this species. It overwinters as a partially grown larva. Adults issue primarily in late August and September.

Black cutworm, *Agrotis ipsilon* (Hufnagel)
(Plate I, Figs. G and H)

Summary description of larva: Adfrontal sutures almost reaching vertical triangles; head capsule brown, varying to lighter brown at sides and generally fuscous with reticulations except along lateral frontal arms where dark brown bars lie. Cuticle granulose, granules strongly convex, isolated, not pointed or in retrorse, small granules interspersed among larger ones. Setigerous tubercle 1 of abdominal segments about one-third as large as setigerous tubercle 2; setigerous tubercle 4 usually larger than the spiracles. Spiracles black

Summary description of adult: Male antennae moderately pectinate in basal half, distal half apparently filiform; female antennae apparently filiform. Forewing of male clay-colored, shaded with darker brown, reddish-brown, or black in basal two-thirds; a black dash extending from the outer margin of the reniform spot which is more heavily outlined in the lower half giving a sickle-shaped appearance; orbicular spot round to tear-shaped; claviform spot an elongate oval. Female forewing similar to male but blackish in basal two-thirds and clay-colored beyond, sometimes paler at base. Hind wing dirty white, darker along wing veins and margins.

Distribution: The black cutworm occurs throughout Louisiana. It is one of the most widely distributed species of cutworms.

Hosts: This is one of the two most important species of cutworms in Louisiana. It feeds on a wide variety of plant species, especially corn and a variety of truck crops. In recent years it has attracted increasing attention as a pest of seedling cotton and soybeans in Louisiana. This worm tends to carry cut-off plant parts into its burrow which is likely to be in moist firm soil. The burrows, 3 to 4 inches long, serve as the daytime home and for food storage.

Seasonal history: Five to six overlapping generations may occur annually in Louisiana. There may be six to seven larval instars requiring 25 to 60 days for development. The total life cycle requires 40 to 65 days. Larvae may be found from March to December. They overwinter primarily as pupae in the soil. Adults may be collected any month during the year.

Claybacked cutworms, *Agrotis gladiaria* Morrison
(Plate II, Figs. A and B)

Summary description of larva: Adfrontal sutures extend to near vertical triangle; head distinctly reticulate; fuscous coloration not limited to submedian arcs. Cuticular granules very small, flat to slightly convex, and nearly contiguous like stones in a wall, without secondary granules. Setigerous tubercle 1 of abdominal segments about half the size of setigerous tubercle 2. Each spiracle set in the dark supraspiracular coloration.

Summary description of adult: Male antennae broadly pectinate. Forewing of male light brown, marked with darker brown and black; veins narrowly black, pale on each side; antemedial line double, visible only near the costa and beneath the cell; subterminal line consisting of pale dots, each preceded by a black wedge; orbicular spot round or elongate, pale, sometimes reduced to a black dot; reniform spot large and dark; claviform spot elongate and dark. Hind wing dirty white, veins and margins darker. No females were available for examination.

The differences between *F. ducens* and *A. gladiaria* are discussed under the former species.

Distribution: The claybacked cutworm has been of more importance in northern Louisiana than in the southern part of the state although it may be found statewide. An outbreak in southwest Louisiana reported by Rings and Arnold (1977) could not be verified by a literature search.

Hosts: The claybacked cutworm has a relatively large host range. In Louisiana this insect feeds mostly on legumes, corn, small grains, and vegetables. The larvae are active at night and hide during the day in earthen tunnels near host plants. This species is less important economically than the granulate or black cutworms.

Seasonal history: The claybacked cutworm develops one generation annually. Unlike most other caterpillar species, this insect overwinters as a partially grown larva. Adults are active in late summer and early fall depositing eggs among host vegetation. Eggs hatch in 10 to 12 days in the fall. Larvae mature in the spring and enter an estivating diapause until pupation in the late summer. Larvae develop through six or seven instars in about 300 days. Total life cycle requires about 1 year.

Palesided cutworm, *Agrotis malefida* Guenée
(Plate II, Figs. C and D)

Summary description of larva: Adfrontal sutures extend almost to vertical triangle; head distinctly reticulate, fuscous coloration not limited to submedian arcs. Skin granulose; granules small, slightly convex, contiguous, and appear like stones in a wall. Secondary granules absent. Setigerous tubercle 1 of abdominal segments about equal in size to setigerous tubercle 2. Spiracles in pale supraspiracular coloration.

Summary description of adult: Antennae of male narrowly pectinate basally, apparently filiform distally; of female, apparently filiform. Forewing of male clay-colored, streaked with black along veins with an area behind the costa and the reniform and claviform spots blackish; orbicular spot elongate and pale or with a dark center. Forewing of female similar to male or darker. Hind wing of male white; of female white, darker along veins and margins

Distribution: This cutworm may be found throughout Louisiana but is most likely to be found in the northern part of the state.

Hosts: Larvae feed on several important crops including cotton, cole crops, potatoes, and legumes. They also form burrows in the soil in which to live during the day and to store food

Seasonal history: The palesided cutworm has four to five generations in Louisiana. They overwinter primarily as pupae, although moths can be collected as early as March in the Baton Rouge area. The six to seven larval instars require about 60 days to develop. An entire life cycle requires about 75 days.

Tobacco budworm, *Heliothis virescens* (F.)

(Plate II, Figs. E and F)

Summary description of larva: The tobacco budworm is very similar to the corn earworm in having a spinose cuticle, but in addition, chalazas 1 and 2 on abdominal segments 1, 2, and 8 are spinose. This species can be distinguished from the corn earworm as third or later instar larvae by the presence of microspines on the chalaza and a molar area on the oral surface of the mandible, characteristics not found on the corn earworm.

Summary description of adult: Antennae filiform. Front wing pale olive with three narrow, dark, oblique bands, the antemedial and postmedial bands preceded by paler ones, the median band usually without one; dark shade of postmedial band not extending into extreme apex of wing; reniform spot outlined by dark scales, indented distally. Hind wing white with a reddish-brown border, much less distinct and complete in males.

This species is very similar to *H. subflexus* (Guenée). Todd (1978) pointed out the differences in the wing patterns of the two species. In *H. subflexus*, the pale band before the dark median band is as distinct as those preceding the antemedial and postmedial bands; the dark shade of the postmedial band extends to the extreme apex of the wing, usually ending in a darker patch of scales; the reniform spot is not completely outlined with dark scales, and the distal margin is straighter. Both species have a terminal row of dots between the veins. the most conspicuous one being at the apex. Males usually have uniformly white hind wings while in females the hind wings have a more or less complete blackish-brown border. Males of these two species are easily separated by differences in male genitalia (Brazzel et al., 1953; Forbes, 1954). The wing pattern of *Schinia trifascia* Hübner is similar to that of *H. virescens* and *H. subflexus*, but the spines on the front tibiae are stouter and more flattened.

Distribution: This species is generally distributed throughout Louisiana.

Hosts: The tobacco budworm, as its name implies, feeds on buds, leaves, and seed heads of host plants In Louisiana, it is a major pest of cotton. Infestations have also been found on roses, clover, and many wild hosts. It is not a pest of corn. Its high degree of resistance to pesticidal chemicals makes it a very formidable pest when high populations develop.

Seasonal history: Occurrence of the tobacco budworm closely coincides with that of the cotton bollworm, although it generally attacks cotton earlier than the bollworm. One generation requires about 50 days. Larvae may be collected from clover in early spring. Three to four generations may develop during a crop year.

Corn earworm, cotton bollworm, tomato fruitworm, *Heliothis zea* (Boddie)

(Plate II, Figs. G and H)

Summary description of larva: The corn earworm (or tomato fruitworm or cotton bollworm) is one of the most important lepidopterous pests in the Americas. It has, uniquely, been given three common names. There is no molar area on the mandible, a characteristic which aids in distinguishing it from the tobacco budworm. The head capsule is light brown. The body color varies greatly among populations from greens and yellows to pinks and browns. The species is also characterized by having a spinose cuticle and large prominent, dark-colored setigerous tubercles (chalazas) 1 and 2 on abdominal segments 1, 2, and 8 which do not bear microspines.

Summary description of adult: Antennae filiform. Forewing of male cream-colored with an olive or orange cast, markings usually less distinct than in female; forewing of female light yellow-brown, shaded with orange or brown, particularly in subterminal area; lines usually indistinct; postmedial line deeply waved, often marked by brown and white dots on veins; terminal line a row of brown dots between the veins; orbicular spot faint, usually with a brown dot in center; reniform spot usually more distinct, brownish. Hind wing cream-colored, usually with veins and a broad external margin brown with two pale marginal spots.

Distribution: The corn earworm is distributed throughout Louisiana.

Hosts: This species has many host plants. Some of the more important crops attacked by it are corn, tomatoes, cotton, alfalfa, clover, soybeans, chrysanthemums, peas, peppers, and sorghum.

Seasonal history: The corn earworm overwinters primarily as pupae in the soil. In early spring larvae can be found in various clovers and many wild hosts in the state. Within a growing season four to five generations develop within the boundaries of Louisiana.

Cotton leafworm, *Alabama argillacea* (Hübner)
(Plate III, Figs. A and B)

Summary description of larva: The head capsule is brown with large conspicuously black setigerous pinacula. Late instar larvae vary markedly in color, especially dorsally. Light forms are green with yellow markings; dark forms have black markings dorsally. There are several longitudinal white stripes extending the length of the body. The most conspicuous characteristics of these larvae are the large black setigerous tubercles (pinacula) over the body. Also, the first pair of abdominal prolegs are reduced to one-third the size of the second, third, and fourth pairs. An extra setigerous tubercle (pinaculum) is located between setigerous tubercles 2 and 4. Spiracles are black.

Summary description of adult: Antennae apparently filiform. Front wing yellow-brown, sometimes with olive hue; all lines incomplete; antemedial, median, and postmedial lines single, dark brown, sometimes with a few white scales; orbicular spot a minute white point surrounded by darker scales; reniform spot horizontal, oval, filled with dark brown and white scales; costa of male swollen at base. Hind wing dirty white, sometimes darker along margins.

Distribution: The cotton leafworm moths migrate into Louisiana and other southern states from South and Central America. The northward annual distribution is limited as larvae feed only on cotton and closely related plant species.

Hosts: Cotton is the one well-known host of the cotton leafworm. Before the extensive use of insecticides for protecting cotton against the boll weevil and bollworm, this species was a serious defoliator of cotton and also stained the fiber with excrement. Adult female moths have occasionally damaged peaches and grapes in Ontario. The proboscis is equipped to feed on soft fruit.

Seasonal history: Two generations usually develop on cotton in Louisiana. It is usually mid- to late summer when moths arrive in cotton fields.

Green cloverworm, *Plathypena scabra* (F.)
(Plate III, Figs. C and D)

Summary description of larva: The head capsule is without marks. The slender caterpillar is uniformly green. It has features similar to loopers but has three pairs of prolegs on abdominal segments 4 to 6. The last instar larva lacks the longitudinal white stripes which are conspicuous on earlier instars. Setae are relatively large and white and arise from definite subconical tubercles with normal skin color. The spiracles are body color with a brown outer rim. The venter is green.

Summary description of adult: Antennae apparently filiform. Labial palpi long, extending forward. Front wing with lower half of postmedial line of raised, usually black scales, more obvious in male; orbicular and reniform spots reduced to a tuft of scales. Front wing of male grayish-black, somewhat paler beyond postmedial line. Front wing of female mottled black, gray, and brown; base of wing to postmedial line blackish, or blackish anteriorly and brownish-gray posteriorly, followed by a paler mottled V-shaped area extending to anterior apical margin; distal part of wing often darker, sometimes with black median and anal dashes and a black line between the orbicular and reniform tufts. Hind wing dark brown or gray and much wider than front wing.

Distribution: The green cloverworm is found throughout Louisiana.

Hosts: This species can be collected from most legumes and many other plants.

Seasonal history: The green cloverworm is usually active from February to November, but in southern areas of the state it is active throughout the year. As many as six generations occur annually.

Velvetbean caterpillar, *Anticarsia gemmatalis* Hübner
(Plate III, Figs. E and F)

Summary description of larva: Head, adfrontals, and front an almost uniform light brown with lighter reticulations. Mandible with two basal teeth shelflike. Setigerous tubercles medium to large in size with light brown setae. Setigerous tubercles 1 and 3 about one-third the size of 2 on meso- and metathorax; setigerous tubercles 1, 2, and 3 of equal size on abdominal segments 1 to 6; setigerous tubercle 1 about half the size of 2 on abdominal segments 7 and 8. Longitudinal white stripes extend length of body; stripe just ventral to spiracular line light yellow; venter above prolegs brown; prolegs and area between tan to green; spiracles tan to brown with brown peritreme.

Summary description of adult: Antennae apparently filiform. Wings alike, pattern very variable—tan, gray-brown, or gray, sometimes with orange or violet tints, variously mottled and shaded; a diagonal line extending from or near anterior apical margin of front wing to inner margin beyond the middle and continued across middle of hind wing; this line yellow- or orange-brown, preceded and sometimes followed by dark brown, sometimes replaced by a dark stripe; subterminal line usually obscure, sometimes represented by pale dots flanked by dark scales, in hind wing often preceded by two conspicuous dark spots. Front wing often with elongate paler area at distal end of costa; orbicular spot a black dot; reniform spot large but usually obscure. Front coxa of male heavily tufted; middle tibia with elongate brush of hair.

Distribution: The velvetbean caterpillar migrates into the United States from Central and South America each year. Severe larval infestations rarely develop north of central Louisiana, Mississippi, and Alabama. However, moths have been collected much further north.

Hosts: Infestations have been common on soybeans in recent years, but serious outbreaks are cyclical occurring at intervals of 6 to 7 years. Historically, this caterpillar was a defoliator of velvetbeans, a crop not grown extensively today.

Seasonal history: Soybeans may become infested with this caterpillar in early summer with three generations of caterpillars developing during the growing period. Late-planted beans are most likely to be severely injured.

A grassworm, *Anicla infecta* (Ochsenheimer)*
(Plate III, Figs. G and H)

Summary description of larva: Like the true armyworm, this caterpillar has mandibles without teeth on the cutting margin and no ribs on the oral surface. There may be fine serrations on the cutting margin of the mandible. Head color gray with dark submedian arcs and light reticulations; reticulations merge anteriorly to form three to five dark lines; narrow nearly white stripe on and caudal to the antennal base; spiracles white with dark rims. Cuticle smooth with color varying—many shades of gray, yellow, or green and some brown; black flecks usually present; a broad longitudinal. almost white, subventral, well-defined stripe bordered ventrally by a darker shade. Each segment from mesothorax to eighth abdominal with a pair of dorsal white spots located just lateral to center of dorsum of segments and bordered with black; setigerous tubercles small and inconspicuous.

Summary description of adult: Antennae apparently filiform. Basal half of collar dark brown to black. Front wing pale gray flecked with black and reddish-brown; antemedial and postmedial lines black, interrupted, often faint or absent; terminal area of wing reddish-brown; subterminal line and anterior apical patch pale; orbicular spot outlined with reddish-brown, often absent; reniform spot outlined with reddish-brown and filled with irregular black spots, outline sometimes fragmented and spots reduced. Hind wing white, narrowly brown along the margins and part of the way up veins. This species is very similar to some species of *Euagrotis*.

Distribution: This species is generally found in grasses throughout Louisiana.

Hosts: Larvae have been collected from various grasses, especially coastal Bermudagrass. It is probably a general grass feeding insect.

Seasonal history: There are three to four generations annually in Louisiana, and adults are present throughout the year. A high percent parasitism apparently holds the populations to low numbers. No epidemic infestation has been found or reported in Louisiana during the past 25 years.

Armyworm, *Pseudaletia unipuncta* (Haworth)
(Plate IV, Figs. A and B)

Summary description of larva: Unlike most caterpillars, the armyworm is a species without definite teeth on the cutting surface of the mandible, but two relatively even cutting edges are apparent on each mandible. Submedian arcs fuscous lateral to adfrontal sutures; reticulations brown to black and covering head capsule except an area mesal to ocellar region. Cuticle is smooth with small setigerous tubercles. Abdominal prolegs with lateral dark gray to brown band extending diagonally down from anterior to posterior.

Summary description of adult: Antennae apparently filiform. Front wings beige to orange-brown dusted with black scales; orbicular and reniform spots pale obscure; a white dot usually preceded and followed by black scales at lower end of reniform; postmedial line reduced to black dots along the veins; a dark oblique line from the anterior apical wing margin to postmedial line, paler above and darker below; often with a row of black dots between the veins along the margin. Hind wing dirty white, darker along the wing veins and margins. This moth is similar in appearance to adults of several *Leucania* species.

Distribution: The armyworm is distributed throughout Louisiana with especially high populations developing in the spring.

Hosts: The armyworm by preference feeds on grasses and small grains. The larvae tend to concentrate in thick stands of grass and in areas where plants have lodged to form a dense canopy. Most serious population build-ups observed in Louisiana have been in the Ouachita and upper Mississippi River valleys, where wheat and oats were primary hosts. The fact that the larvae tend to cut off seed-heads makes it a serious pest in grain fields.

Seasonal history: Some years, hordes or armies of this species build up in the spring and cause extensive loss in grain yields. There are three to four generations annually. The winter is passed primarily as pupae in the soil. A few larvae can be found in December and January. In February larvae are often found in large numbers in dense rye grass and small grain fields. Large injurious populations of late instar larvae may occur from late March into May. Larval populations are generally very low during other times of the year. A generation develops in about 60 days. Parasites and predators are probably responsible for low populations after the spring brood matures.

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*No common accepted name for these species.

Fall armyworm, *Spodoptera frugiperda* (J. E. Smith)
(Plate IV, Figs. C and D)

Summary description of larva: The head capsule is generally brown and partially covered with darker brown to black reticulations with narrow submedian areas and light tan to near white adfrontal areas. The cuticle is clothed with dense microscopic granules. Setigerous tubercles are as large as or larger than the spiracles, unlike other *Spodoptera* spp., and generally dark gray to brown in color. The overall body color varies within a population. Some larvae may be relatively light green to brown whereas others appear to be almost black except for longitudinal white lines along the subdorsal and subspiracular areas. The mid-dorsal narrow white line is not continuous. The venter is tan with yellow and reddish flecking. Unlike the true armyworm, all species of *Spodoptera* have teeth on the mandibles.

Summary description of adult: Antennae filiform. Front wing of male similar to *S. ornithogalli* but with much less contrast in shades, generally with upper half of wing in dark shades of gray and brown and lower half to postmedial line or beyond pale gray or brown, an oblique white bar in anterior apical corner; orbicular spot oblique, pale brown, narrowly outlined by dark scales, outer margin sometimes confluent with oblique pale shade which usually extends from the costa to Cu$_1$; reniform indistinct with a white spot beneath it. Ventral surface of thorax dark gray. Front wing of female dark brownish gray, lines usually indistinct; orbicular spot obliquely elongate, narrowly outlined in black with a pale rim around the dark center. Hind wing translucent white with a partial narrow black border, veins often dark distally. Wingspread 25 to 35 mm. Males are most similar to yellow-striped armyworm males, and females are sometimes confused with beet armyworms.

Distribution: The fall armyworm generally does not overwinter in the United States, except in extreme southern coastal areas. The collection of numerous larvae from Chinese cabbage in Baton Rouge in late December, 1979, indicates that some years this insect may survive a mild winter. However, migration into the state from more southern areas contributes to higher populations. Successive moth flights during the summer result in infestations over the entire state each year.

Hosts: The fall armyworm is a general grass feeder. It is one of the most serious pests of corn, pasture grasses, and small grains in the state. It was troublesome in some fields of seedling soybeans in 1980. The larvae are sometimes called grassworms and also corn budworms because they feed on the whorl of young corn plants.

Seasonal history: There may be up to four broods during the growing season in Louisiana. Most serious infestations develop in summer and early fall, especially if biological control agents fail to develop in sufficient quantities to suppress the populations. In most years, it is necessary to use direct applied control to prevent economic injury especially on young corn and pasture grasses.

Beet armyworm, *Spodoptera exigua* (Hübner)
(Plate IV, Figs. E and F)

Summary description of larva: The beet armyworm is often confused with the fall armyworm. The head is brown with conspicuous dark reticulations. However, the very smooth shiny cuticle with small setigerous tubercles, no more than half the size of the spiracles, which on the fall armyworm are large, dark, and very conspicuous, serves to separate the two species. Color also varies markedly among beet armyworm larvae from a light green to an almost black dorsum. There are more or less linear dark subdorsal markings on each abdominal segment. There are usually five interrupted narrow white lines down the dorsum lateral to a central dark gray stripe, a continuous white line subdorsally, and another just ventral to the spiracles. A dark spot in the supraspiracular area of the mesothorax is characteristic of most larvae but may be obscure in dark or very light forms. White to light yellow spots occur just dorsal to the spiracles especially on dark forms. The venter is light green and mottled with irregular short white lines.

Summary description of adult: Antennae filiform. Front wing light brownish gray marked with dark brown and white scales, lines usually indistinct, orbicular spot round, cream-colored or with orange center;

eniform spot indistinct, filled with ground color. Hind wing white, veins and wing margin brown.

Distribution: The beet armyworm occurs over the entire state. It is a common pest of cotton in Central America.

Hosts: In Louisiana, beet armyworms have been troublesome as defoliators of cotton, alfalfa, and crucifers. This worm also feeds on various weeds.

Seasonal history: Although the winter is passed primarily as pupae, many larvae have been collected from cole crops at Baton Rouge in mid-December. Larvae have been collected in March in Mississippi and from cotton and alfalfa in several areas of north Louisiana in summer. There are at least four generations annually.

Southern armyworm, *Spodoptera eridania* (Cramer)
(Plate IV, Figs. G and H)

Summary description of larva: Head capsule light brown with faint, inconspicuous reticulations. Setigerous tubercles inconspicuous, setae small. Ab-

dominal segments with dark subdorsal markings more or less triangular; a narrow, almost continuous middorsal white stripe and a prominent yellowish subspiracular longitudinal stripe interrupted by a dark spot on first abdominal segment. Large white spot usually just posterior and dorsal to spiracle.

Summary description of adult: Antennae of male finely serrate; of female, filiform. Front wing streaked with cream, gray, light brown, and black, usually without a fine dark basal dash and with an elongate oblique white mark across the posterior apical corner; reniform spot usually evident as a dark spot, sometimes followed by a black band extending to outer margin. Hind wing white with few dark marks on margin.

Distribution: This species may be found over the entire state but especially in the southern half.

Hosts: The southern armyworm has many hosts. It is a serious pest of sweetpotatoes, tomatoes, and chrysanthemums in Louisiana. It has also been collected from leguminous crops, cotton, cucurbits, crucifers, and various weeds.

Seasonal history: This armyworm overwinters as pupae. There are four to five generations annually with first adult activity in early spring. Larvae have been collected during the entire growing season and in November from chrysanthemums in greenhouses.

An armyworm, *Spodoptera sunia* (Guenée)*

(Plate V, Figs. A and B)

Summary description of larva: Adfrontal areas and reticulations yellowish to brown; head brown with submedian arcs small, black, and intersected by reticulations. Tubercles small and yellow with very small setae. Body color generally gray to yellow and dark brown; pinkish flecks numerous over venter. Middorsal stripe broad, yellow to brown, and narrowing at each end to bisect the prothoracic shield and suranal plate. Dorsum mottled with gray, brown, and black. Each subdorsal dark marking possessing a distinctive white inner (mesal) spot or mark which distinguishes the species from all others in *Spodoptera*. Spiracles oval, brown to black with lighter centers and black peritremes with outer white margins. Conspicuous white spot just posterior and dorsal to spiracle. Larvae vary markedly with the white spots in the subdorsal triangles generally a consistent character.

Summary description of adult: Antennae of male finely serrate; of female filiform. Front wing streaked with gray, white, light brown, and black with a fine black basal dash and often with an oblique white mark across the posterior apical corner; reniform spot faint. Hind wing white with few dark marks on margin.

This species is very similar to *S. eridania*. but in *S sunia* the fine black basal dash is more distinct and the oblique white mark across the posterior apical corner is less elongate. The genitalia of the two species are different.

Distribution: This species does not presently occur in Louisiana. Infestations have been detected in south Florida. Larvae examined were collected from cotton in Guatemala.

Hosts: This species is apparently a serious defoliator of cotton in Central America.

Yellowstriped armyworm, *Spodoptera ornithogalli* (Guenée)

(Plate V, Figs. C and D)

Summary description of larva: Common characteristics used by some people to distinguish this species are the conspicuously white adfrontal areas and fuscous head capsule with lighter brown reticulations on the lateral epicranium. Body color varies among larvae of this species. Elongated, triangular, dark subdorsal areas with a white line passing through are usually present on abdominal segments 1 through 8. Ventral to the dark subdorsal area is a bright yellow longitudinal stripe within which are usually three to four irregular narrow white stripes. Spiracles are light brown with black rims located in the ventral edge of a dark spiracular band. Abdominal segment 1 usually has a dark circular spot laterally which may be obliterated in late instars.

Summary description of adult: Antennae filiform. Wing pattern complex; front wing of male light brown with blue-gray or sometimes violet shades, pale brown in lower median area with white patches in anterior and posterior apical corners; an off-white diagonal bar covering the narrow oblique orbicular spot and extending almost to the costa and postmedial line; upper part of reniform spot pale, middle brown, veins at lower end white; black crescents along apical margin separate from preceding white line; front wing of female similar; pattern more subdued, blue-gray in lower median area. Hind wing translucent white usually with narrow border and veins blackish. Wingspread, 32 to 43 mm.

Females of *S. latifascia* have often been confused with females of *S. ornithogalli*. In *S. latifascia* the black crescents along the apical margin are usually connected by a stalk to the preceding white line, while in *S. ornithogalli* the black crescents are almost always separate from the the preceding white line. The two species have different genitalia.

Distribution: The yellowstriped armyworm can be found throughout Louisiana.

Hosts: This species feeds on many plants. It is a general pest of garden crops and can be collected from

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* No common accepted name for these species.

various leguminous crops, cotton, soybeans, and bedding plants.

Seasonal history: There are four to five generations annually in Louisiana. It overwinters primarily as pupae in the soil. Young larvae may be found among legumes and garden plants in early April.

An armyworm, *Spodoptera latifascia* (Walker)*
(Plate V, Figs. E and F)

Summary description of larva: Head capsule brown with faint yellow to tan reticulations. Submedian arcs brown, narrow; setae brown; tubercles small and yellow to light brown. Body grayish-green to reddish-brown. Mid-dorsal stripe obscure, faintly whitish-pink on several segments with narrow stripe bisecting prothoracic and anal shields. Dorsum clothed with white flecks, other flecks varying from gray and greenish-blue to almost black. Subdorsal markings dark brown to black, varying from triangular to semicircular and sometimes flecked with light markings but with no white line passing through. Subdorsal marks vary in size, shape, and location or are reduced on meso- and metathorax and abdominal segments 1 to 7. Supraspiracular area consisting of two semi-parallel lines of equal width, the upper one consisting of three narrow pink and white lines on gray to brown; subventral area with broad tan stripe just ventral to spiracles. Spiracles oval, brown to black with pale centers; peritremes black with white outer margins. This species is sometimes difficult to distinguish from *Spodoptera dolichos*, *S. eridania*, and *S. ornithogalli*.

Summary description of adult: Antennae filiform. Front wing of male violet-gray, pale yellow-brown in lower median half, and gray and white between the postmedial and subterminal lines; an off-white diagonal bar extending from the costa through the orbicular spot, fading out before the postmedial line; reniform spot indistinct, pale yellow-brown, violet-gray in middle; black crescents along apical margin usually connected by a stalk to preceding white line. Front wing of female very similar to *S. ornithogalli*. Hind wing translucent white usually with a narrow dark border; veins sometimes dark. The differences between females of *S. ornithogalli* and *S. latifascia* are discussed under the former species.

Distribution: This armyworm was taken from cotton in late summer in Baton Rouge. Adults were collected in East Baton Rouge and St. John the Baptist parishes. It is probably a species of limited distribution in the southeastern United States.

Hosts: All larval specimens examined were collected from cotton in Baton Rouge. Levy and Habeck (1973) described larvae collected in Florida.

Seasonal history: No detailed information on the seasonal history of larvae of this species is available. Several hundred specimens were collected from cotton in August and September. Adults were collected from February 9 to December 10 in Baton Rouge.

An armyworm, *Spodoptera dolichos* (F.)*
(Plate V, Figs. G and H)

Summary description of larva: Head capsule brown with white adfrontals and light brown reticulations, most conspicuous on lateral epicranium. Subdorsal markings on mesothorax large, more or less trapezoidal in shape, and about equal in size to those on eighth abdominal segment. Body color varies from mottled gray to dark brown; supraspiracular stripe orange. Spiracles brown with black rim. Lateral spot on first abdominal segment not apparent. Larvae collected in early winter were light gray with a confused pattern of dark subdorsal markings. Most longitudinal stripes are obliterated or obscure.

Summary description of adult: Antennae filiform. Front wing pattern similar to *S. ornithogalli* and *S. latifascia* in shades of brown washed with violet and some gray and marked with white. This species differs from other *Spodoptera* spp. in having two black and brown stripes dorsally on the thorax and in having a white, usually distinct, bar extending upward and outward from the middle of the outer edge of the reniform spot. Wingspread, 42 to 48 mm.

Distribution: This species has been collected in limited numbers in south Louisiana. It is likely to be most abundant in the Gulf Coast States and Central America.

Hosts: The larvae examined were collected from Chinese cabbage in Baton Rouge. Tomatoes, cotton, sweetpotatoes, tobacco, and various weeds also serve as hosts.

Seasonal history: Larvae examined were collected in December. Three different instars were collected indicating that the winter may be passed as larvae and pupae. Adults were collected from May 16 to December 7 in Baton Rouge.

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* No common accepted name for these species.

Plate I

Larva

Adult

Variegated Cutworm

Figure A

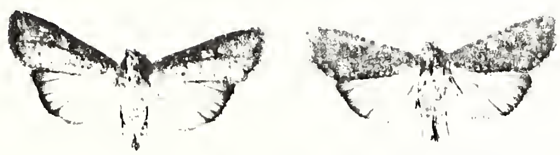


Figure B

Granulate Cutworm

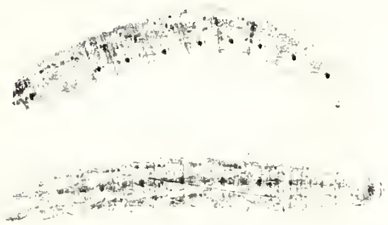


Figure C

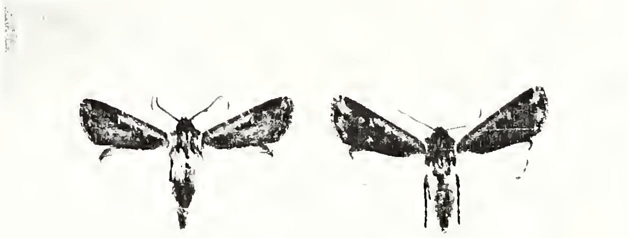


Figure D

Dingy Cutworm

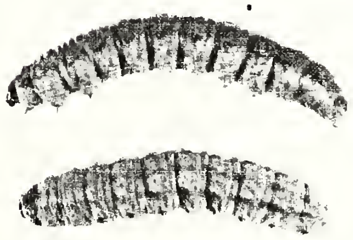


Figure E

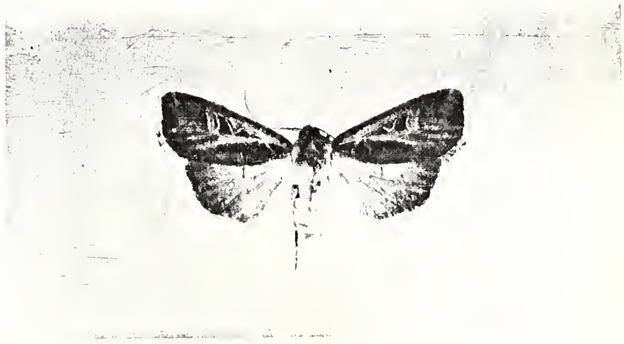


Figure F

Black Cutworm

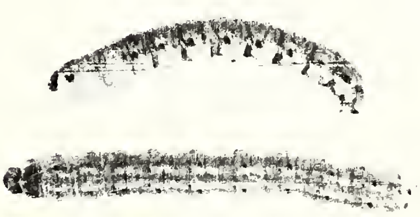


Figure G

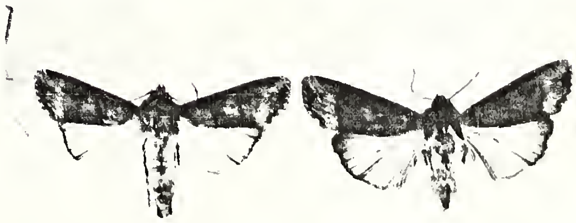


Figure H

Plate II

Larva

Adult

Claybacked Cutworm

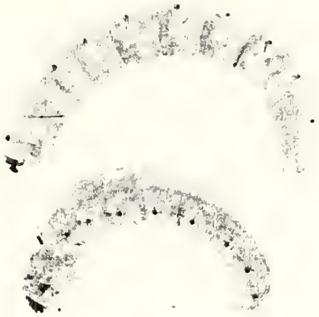


Figure A

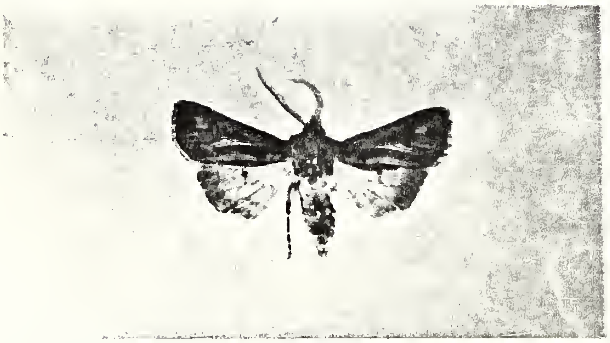
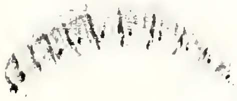


Figure B

Palesided Cutworm



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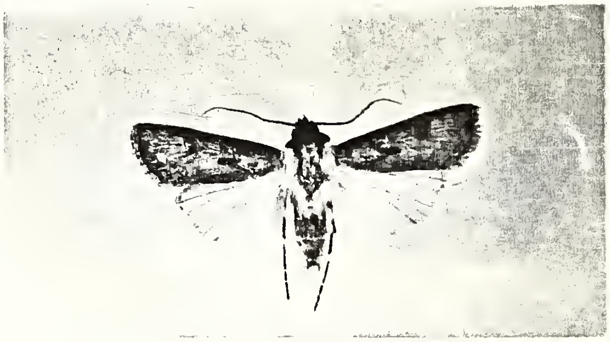
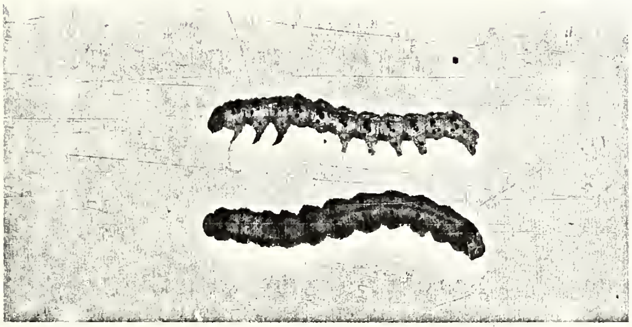


Figure D

Tobacco Budworm



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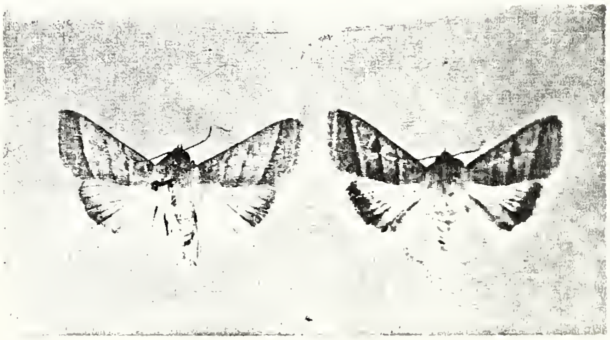


Figure F

Cotton Bollworm (Corn earworm, tomato fruitworm)

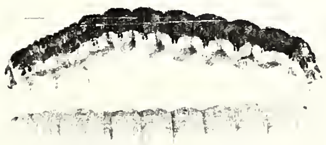


Figure G

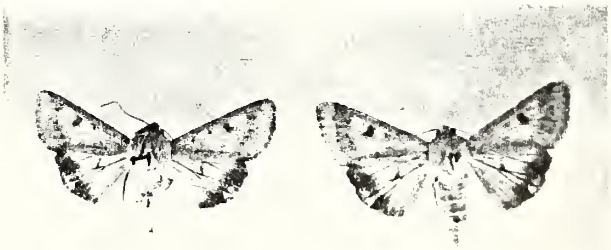


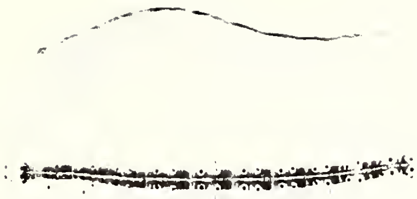
Figure H

Plate III

Larva

Cotton Leafworm

Adult



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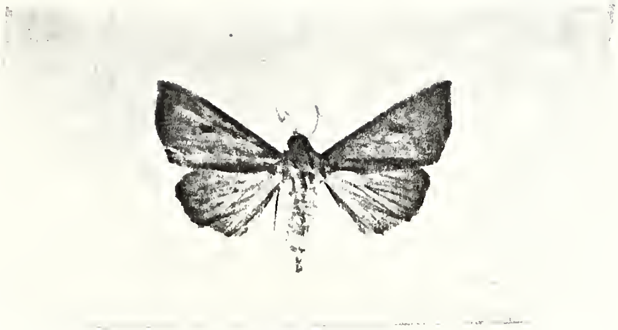


Figure B

Green Cloverworm

Figure C

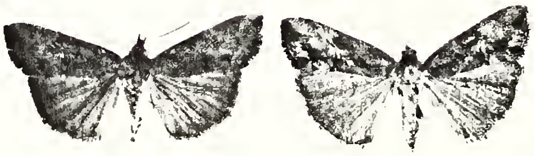
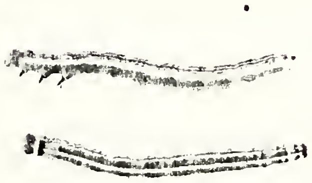


Figure D

Velvetbean Caterpillar



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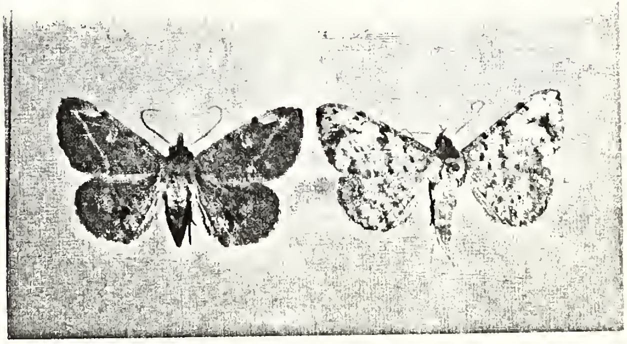


Figure F

Anicla infecta

Figure G

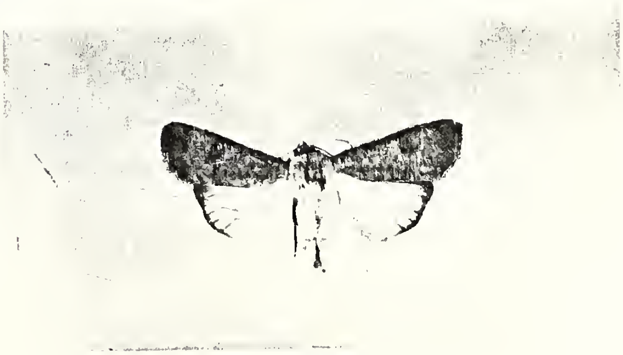


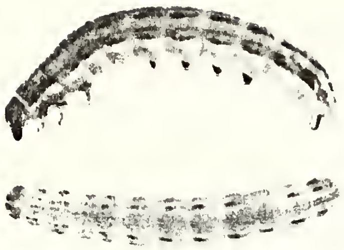
Figure H

Plate IV

Larva

Adult

Armyworm



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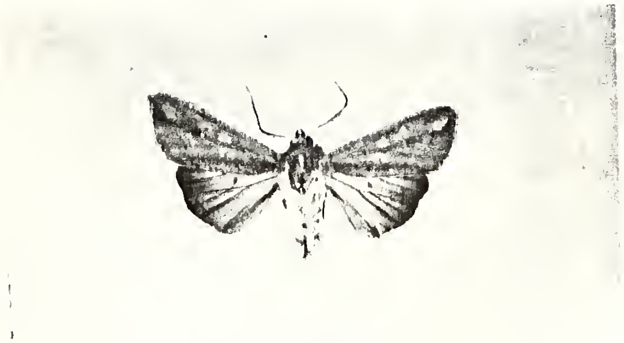


Figure B

Fall Armyworm

Figure C

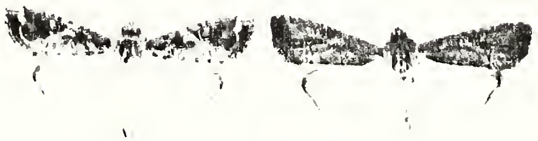
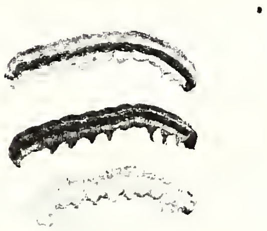


Figure D

Beet Armyworm



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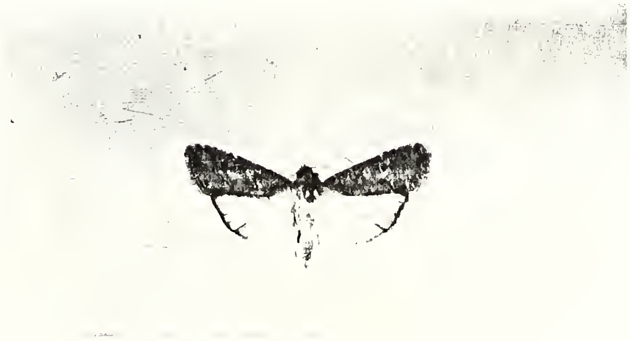


Figure F

Southern Armyworm

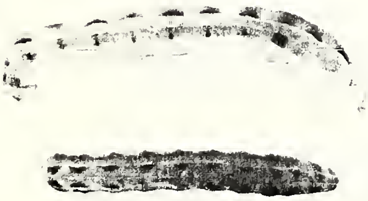


Figure G

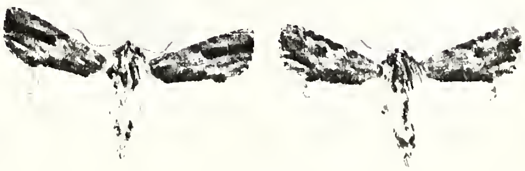


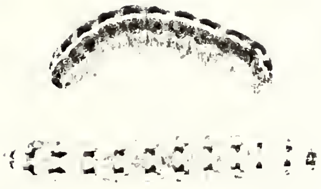
Figure H

Plate V

Larva

Adult

Spodoptera sunia



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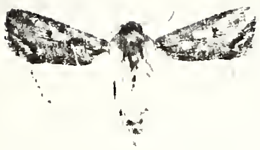
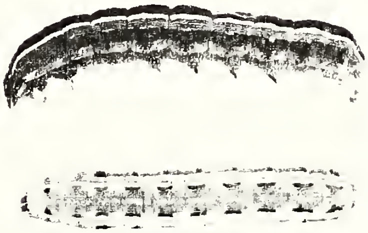


Figure B

Yellowstriped Armyworm



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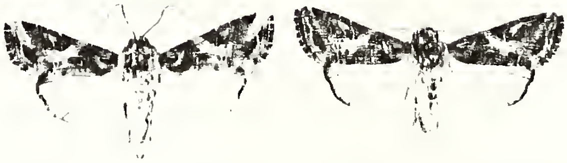
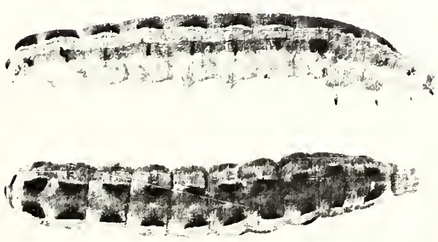


Figure D

Spodoptera latifascia



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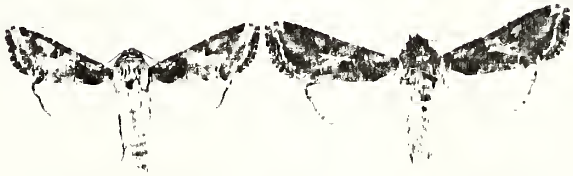

Figure F

Spodoptera dolichos

Figure G

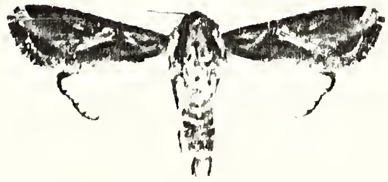

Figure H

Glossary of Terms

adfrontal areas: two oblique sclerites on the front of a caterpillar head extending from near the antennal base to the epicranial suture where they join.

adfrontal sutures: sutures (seams) between the adfrontal areas and the epicranium.

anal prolegs: prolegs on the last abdominal segment, not usually referred to as abdominal prolegs.

basal: toward the end attached to the body.

bisetose: consisting of two setae or hairs, as on a tubercle.

cervical triangle: the V-shaped space at the top of the head where the two halves of the head capsule meet.

chaetotaxy: pattern of primary setae (hairs) on the body of a caterpillar.

chalaza: a scleritized elevation, tubercle, or projection of cuticle (skin) bearing one or more setae or microspines.

claviform: elongate spot located behind the orbicular spot in the front wing.

collar: two scale-covered lobes on the prothorax.

coronal suture: the stem of the Y-shaped epicranial suture which extends from the junction of the adfrontal areas to the vertical triangle.

costa: the thickened, elevated ridge on the anterior margin of the front wing of moths.

coxa: the leg segment next to the body.

cranium: the head capsule.

crochets: the sclerotized claws or hooks on the abdominal prolegs.

discal cell: an area in the middle of the wing without veins.

distal: toward the end away from the body.

dorsal: the top or back of an insect.

dorso-meson: toward the center of the back or upper body.

dorsum: the back or upper surface of the body of an insect.

ecdysis: moulting or casting the skin.

epicranial suture: a suture which separates the two halves of the upper head surface including the two lateral arms (adfrontal sutures) on either side of the front.

epicranium: the scleritized cranium exclusive of the front.

ferruginous: rusty red-brown in color.

filiform: thread-like.

frenulum: one (male) or several (female) bristles on the anterior basal edge of hind wing.

front: in larvae, part of the head bounded by the frontal and epistomal sutures.

front: in moths, the front of the head between the eyes.

frontal suture: a suture which bounds the front laterally.

fuscous: dark brown, approaching black: a mixture of red and black.

genitalia: the reproductive organs.

instar: any of several stages of development in the life of a caterpillar.

Kappa group: the seta(e) in the prespiracular group on a tubercle just anterior to the spiracle of prothorax.

larva: a caterpillar or worm.

labial palpi: a pair of structures on thelabium (mouthparts).

lateral: on the side.

mandible: the opposable appendages (jaws) of a caterpillar located beneath labrum or upper lip

meson: the middle of the upper body or dorsum.

mesoseries: refers to the crochets or hooks arranged longitudinally on the mesal side of an abdominal proleg.

mesothorax: the middle or second thoracic segment.

metathorax: the last or third thoracic segment.

microspine: small, microscopic spine on body wall of larvae.

moult: to shed the cuticle (skin).

orbicular: a spot in the discal cell of the front wing.

ocelli: a pair of simple eyes behind the antennae, hidden beneath hair.

pectinate: comb-like.

peritreme: the sclerotized rim around a spiracle.

pinaculum: a small, flat sclerotized area of the body wall bearing setae.

planta. the distal part of an abdominal proleg which bears the crochets.

proleg: a fleshy abdominal leg bearing crochets.

primary setae: setae (hairs) with a definite arrangement on the body of caterpillars.

prothorax: the first segment of the thorax located immediately behind the head.

reticulations: the mottled pattern of color, usually brown, white, and black, on the head.

reniform: a usually kidney-shaped spot in the discal cell of the front wing.

sclerotized: hardened in definite areas.

serrate: saw-like, with notched edges like saw teeth.

seta: a hair.

setigerous: bearing setae.

spinose: possessing or covered with spines.

spiracle: pore for breathing; an external opening.

spiracular line: the line in which the spiracles are located.

stadium: time interval between any two moults of a caterpillar.

subequal: nearly or almost alike in size or structure.

subdorsal: to the side of dorsal; between dorsal and lateral.

submedian arc: the fuscous or dark brown to black area lateral to the adfrontal area on the head capsule.

subspiracular. just below the spiracles.

subventral: just above the bases of prolegs.

supraspiracular: area just above the spiracles and extending to the subdorsal area.

suture: a line or seam which separates two sclerites or body plates.

tibia: a segment of the leg located between the femur and the tarsi (feet).

tubercle: an elevated area in the body wall usually bearing setae; pinacula and chalaza are two kinds of tubercles.

uniordinal: crochets or hooks of one length.

uniserial: crochets or hooks in a single line.

venter: the bottom, belly, or undersurface.

vertical triangle: the area at the top of the head where the coronal suture terminates; cervical triangle.

wart: a tubercle.

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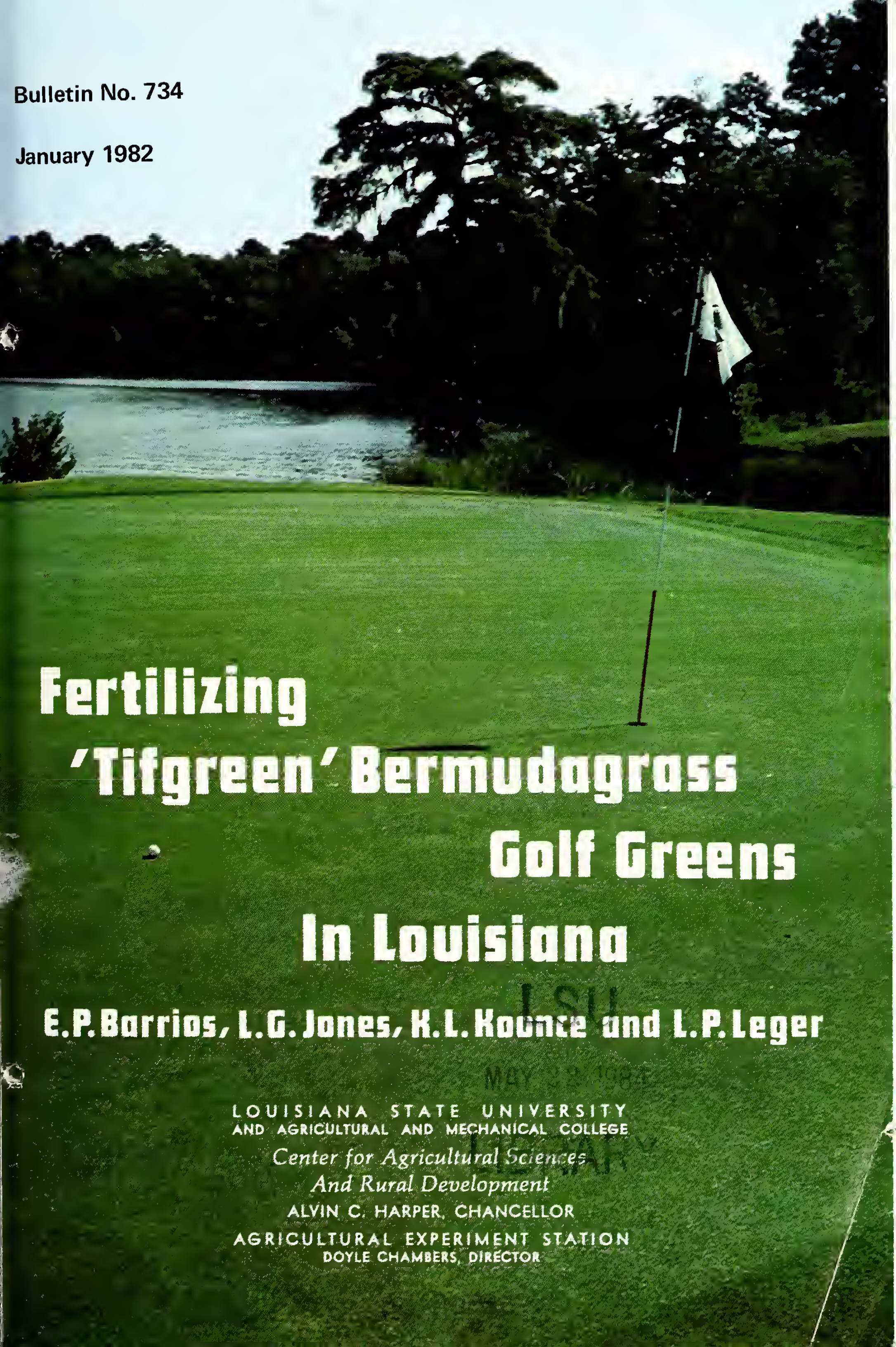

Bulletin No. 734

January 1982

Fertilizing 'Tifgreen' Bermudagrass Golf Greens In Louisiana

E. P. Barrios, L. G. Jones, K. L. Kounce and L. P. Leger

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Acknowledgments

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E30

Fertilizing 'Tifgreen' Bermudagrass Golf Greens in Louisiana

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Introduction

'Tifgreen' bermudagrass provides the most desirable playing surface on golf putting greens in the southern United States during the warm spring and summer seasons. Maintaining this turfgrass to provide the optimum playing surface and appearance requires relatively large amounts of nitrogen (N), phosphorus (P), and potassium (K) fertilizers, especially with the high rates of rainfall and generally warm temperatures found in Louisiana.

Bermudagrass quality is influenced principally by N *(2, 24)*[3]. Frequent applications of nitrogen fertilizer should be made from the beginning of spring growth until overseeding with a winter grass in the fall. Heavy concentrations of foot traffic on golf greens require that they be constructed with large percentages of sand and smaller percentages of organic matter and topsoil *(8)*. The high proportion of sand in greens results in considerable leaching, and N supplied in soluble sources can quickly become unavailable to turfgrass on the surface of greens. Therefore, slowly soluble types are generally used. These also afford greater safety margins against foliar injury than more soluble forms *(10, 11, 22, 24)*. Sources such as ureaformaldehyde and urea are used principally to provide N in the form of mixed fertilizers for golf greens.

Phosphorus affects the establishment, rooting, maturation, and reproduction of turfgrasses *(4)*. Responses to P applications reportedly have occurred when the soil level was less than 5 parts per million (ppm) of bicarbonate extractable P *(15)*. Some research has indicated that turfgrasses vary in their response to P supply *(5)*. Bermudagrass is believed to be low in P absorption in comparison with some other turfgrasses, but no published research has proven this supposition. However, P had a greater influence on the yield of Kentucky bluegrass than on that of red fescue *(14)*. Extractable P[4] levels during a 1973 to 1978 soil analysis survey of 1,150 golf greens in Louisiana showed that 52 percent varied from 100 to 400 ppm, with 33 percent higher than 400 ppm, at the 0 to 6-inch sampling depth *(6)*.

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[3] Italic numbers in parentheses refer to Literature Cited, page 33.

[4] Extracted with 0.1N HCl + 0.03N NH_4F at a soil-to-extractant ratio of 1:20.

Potassium sources, rates, and frequencies have been shown to affect turf quality *(3, 13)*. A soil analysis survey of 1,150 Louisiana golf greens from 1973 to 1978, at the 0 to 6-inch depth, showed that 91 percent contained from 25 to 200 ppm of extractable K[5], 63 percent had 25 to 100 ppm, and 7 percent exceeded 200 ppm *(6)*. The efficiency of utilization of applied K is thought to be relatively low in golf green media, however, due to leaching losses during the long, moist growing season in Louisiana. Relatively large amounts of K are required for increased root, stolon, and rhizome development in turfgrasses. Heat, cold, and drought tolerance are also influenced by K levels in the plant *(1, 4, 12, 17, 19, 21)*.

Some objectives in this research were to study the effects of various rates, application frequencies, and sources of N on the quality and yield of 'Tifgreen' bermudagrass grown on a golf green in a warm, high-rainfall environment. A single source of P or K was also used at several rates and/or ratios of these elements in other studies to determine their influences on growth and quality responses of the same turfgrass produced in a similar environment and root-zone medium.

Experimental Procedure

Eight golf greens of 750 square feet each were constructed at the LSU Agricultural Experiment Station's Burden Research Center, Baton Rouge, in 1972 and 1973 according to U.S. Golf Association specifications *(8)*. The medium consisted of 70 percent sand (0.3 percent 0.05 mm to 0.10 mm; 10.5 percent 0.10 mm to 0.25 mm; 42.5 percent 0.25 mm to 0.50 mm; 25.7 percent 0.50 mm to 1 mm, and 11.1 percent 1 mm to 2 mm), 20 percent sphagnum peat moss, and 10 percent topsoil (Cascilla silt loam). Materials were measured by volume, mixed off-site with a 7 cubic yard cement truck, and placed on an area provided with a gravel base and subsurface drainage. Initial depth of the greens mix was 16 inches, settling to 14 inches by the fall of 1973. Infiltration rate of the completed greens (April, 1973) was approximately 5 inches per hour with a moisture retention rate from 1.5 percent at 15 atmospheres to 15.1 percent at 40 atmospheres, providing 0.2 inch of available moisture per inch of medium. Bulk density was 1.5 grams per cubic centimeter, with a capillary pore space of 23 percent and noncapillary pore space of 21 percent.

Financial limitations somewhat restricted the size of each green. Therefore, provisions were made to eliminate possible experimental error resulting from this source. Plots were 3 x 15 feet each, separated by borders 8 inches wide, with fiberglass dividers placed between them to a depth of 12 inches below the surface. Turfgrass between plots was killed regularly with a contact herbicide to prevent growth from one plot to another. Replications in the greens in the K treatment were also separated from one another by fiberglass dividers, but the N and P replications (greens) were separated only by 5-foot-wide borders of topsoil (Cascilla silt loam). Shoulders of the greens were composed of the same topsoil and were also planted with 'Tifgreen' bermudagrass.

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[5] Extracted with 1N NH_4OAc buffered at pH 7.0 at a soil-to-extractant ratio of 1:20.

The pH of the mixed medium at the 0 to 6-inch depth was adjusted from 4.9 to between 6.5 and 7.0 by the addition of agricultural lime (100 mesh) during 1973 and was maintained in that range through 1980. Extractable calcium (Ca) averaged 1,200 ppm and magnesium (Mg) averaged 100 ppm during the period of this research. Initial analyses of the medium (0 to 3-inch depth) showed 14 and 15 ppm of extractable P and K, respectively *(6)*. Consequently, a pre-plant starter fertilizer was applied at the rate of 5 pounds of available P_2O_5 (single superphosphate), 5 pounds of available K_2O (potassium chloride), and 2 pounds of N (ammonium nitrate) per 1,000 square feet 1 month prior to planting and incorporated into the medium to a depth of about 4 inches. Greens in the N and K treatments were planted with 'Tifgreen' bermudagrass in September 1973 by sprigging at the rate of 10 bushels per 1,000 square feet. Although rainfall fluctuated considerably from year to year, approximately 2 inches of moisture per week were provided during the growing season by rainfall supplemented with an underground irrigation system.

The turfgrass was mowed daily to a height of about ¼ inch using a greens mower equipped with a basket to remove clippings. Plots were verticut three times each season to control thatch, aerified, and topdressed twice a year with the same materials used to construct the greens. Data were collected when 75 percent or more of the plot area consisted of actively growing bermudagrass. Yields of clippings were obtained from dry grass, unmowed for the previous 24-hour period, with a modified greens mower 18 inches wide with an attached grass catcher. The same clippings were also used for foliar analyses to determine tissue concentrations of N, P, K, copper (Cu), iron (Fe), Mg, manganese (Mn), sulfur (S), and zinc (Zn). Foliar samples were dried at 95°F for 48 hours prior to analysis. Turf quality was evaluated by a panel of five faculty members and golf superintendents within 48 hours after yield data were obtained. The panel was composed of the same members throughout the research period, with ratings based on a visual scale of 1 (poorest) to 9 (best) in appearance and texture. Turfgrass was not considered of acceptable quality if the rating was less than 6.5. Five to 10 sets of yield records and quality evaluations were made in each growing season, depending on environmental conditions.

Nitrogen Plots

The experimental design was a randomized block with three replications (greens) and 16 treatments, utilizing three sources and several rates and application frequencies of soluble and slowly soluble N fertilizers. Sources used included ammonium nitrate, ureaformaldehyde (UF), and activated sewage sludge (Milorganite) during 1974, 1975, and 1976; ammonium nitrate, isobutylidene diurea (IBDU), and Milorganite in 1977 and 1978; and sulfur-coated urea (SCU), Hi-Organic (activated sewage sludge), and Milorganite in 1979 and 1980 (Tables 1, 2, and 3). Fertilizers were applied from April to October each year and watered in by hand sprinkler immediately after application to avoid foliar injury.

Table 1.—Nitrogen treatments, April to October, 1974, 1975, and 1976

Treatment no.	Source	N (lb/1,000 ft²)	Frequency	Total N/yr (lb/1,000 ft²)
1	Ammonium nitrate	1	Monthly	6
2	Ammonium nitrate	1	Biweekly	12
3	Ammonium nitrate	2	Monthly	12
4	Ammonium nitrate	2	Biweekly	24
5	Ammonium nitrate	3	Monthly	18
6	Ureaformaldehyde	1	Monthly	6
7	Ureaformaldehyde	2	Monthly	12
8	Ureaformaldehyde	3	Monthly	18
9	Ureaformaldehyde	4	Monthly	24
10	Ureaformaldehyde	6	Monthly	36
11	Milorganite	2	Monthly	12
12	Milorganite	4	Monthly	24
13	Milorganite	12	Bimonthly	36
14	Milorganite	6	Bimonthly	18
15	Milorganite	8	Bimonthly	24
16	Milorganite	18	Trimonthly	36

Table 2.—Nitrogen treatments, April to October, 1977 and 1978

Treatment no.	Source	N (lb/1,000 ft²)	Frequency	Total N/yr (lb/1,000 ft²)
1	Ammonium nitrate	1	Monthly	6
2	Ammonium nitrate	1	Biweekly	12
3	Ammonium nitrate	2	Monthly	12
4	Ammonium nitrate	2	Biweekly	24
5	IBDU	2	Monthly	12
6	IBDU	4	Monthly	24
7	IBDU	4	Bimonthly	12
8	IBDU	6	Bimonthly	18
9	IBDU	12	Trimonthly	24
10	IBDU	18	Trimonthly	36
11	Milorganite	2	Monthly	12
12	Milorganite	4	Monthly	24
13	Milorganite	4	Bimonthly	12
14	Milorganite	6	Bimonthly	18
15	Milorganite	12	Trimonthly	24
16	Milorganite	18	Trimonthly	36

Table 3.—Nitrogen treatments, April to October, 1979 and 1980

Treatment no.	Source	N (lb/1,000 ft^2)	Frequency	Total N/yr (lb/1,000 ft^2)
1	SCU	1	Monthly	6
2	SCU	2	Monthly	12
3	SCU	2	Bimonthly	6
4	SCU	4	Bimonthly	12
5	Hi-Organic	1	Monthly	6
6	Hi-Organic	2	Monthly	12
7	Hi-Organic	3	Monthly	18
8	Hi-Organic	2	Bimonthly	6
9	Hi-Organic	4	Bimonthly	12
10	Hi-Organic	6	Bimonthly	18
11	Milorganite	1	Monthly	6
12	Milorganite	2	Monthly	12
13	Milorganite	3	Monthly	18
14	Milorganite	2	Bimonthly	6
15	Milorganite	4	Bimonthly	12
16	Milorganite	6	Bimonthly	18

Medium samples were taken at the 0 to 3-inch depth periodically (1974 through 1980) to monitor pH and levels of extractable P and K. These elements were applied when necessary (as superphosphate and potassium chloride) to maintain levels of P and K at about 300 and 100 ppm, respectively.

Phosphorus Plots

These greens were sprigged in August of 1975 with 10 bushels per 1,000 square feet of 'Tifgreen' bermudagrass. The experimental design was a randomized block with three replications (greens). Each replication was composed of three sub-plots (250 square feet each) with low, medium, and high levels of extractable P, modified by pre-plant applications of superphosphate in 1974 and 1975 from the initial 14 ppm of extractable P. The low (A) contained 15 to 62 ppm; medium (B), 72 to 150 ppm; and the high (C), 151 to 300 ppm of extractable P when the experiment was initiated in the spring of 1976. Fertilizer treatment plots consisted of three varying P (superphosphate), but constant N (ammonium nitrate) and K (potassium chloride) ratios, which were applied across all sub-plots at two different rates on a monthly frequency (May to October) in 1976, 1977, and 1978 (Table 4).

Samples from the medium were obtained at the 0 to 3-inch depth periodically to monitor pH and levels of extractable P and K. Additional P from superphosphate was applied to the sub-plots when necessary to maintain the approximate levels described above for the duration of this research.

Table 4.—Fertilizer treatments, May to October, 1976, 1977, and 1978

Treatment no.	Ratio[1] (N-P-K)	Rate per application (lb/1,000 ft^2)	Total/yr (lb/1,000 ft^2)
1	16-4-8	10	50
2	16-8-8	10	50
3	16-16-8	10	50
4	16-4-8	20	100
5	16-8-8	20	100
6	16-16-8	20	100

[1] N = ammonium nitrate, P = superphosphate, K = muriate of potash.

Potassium Plots

This research was designed on two golf greens as a randomized block, with four replications (each 375 square feet). One K source (KC1—potassium chloride), several rates, and three application frequencies were used (Table 5). Treatments were applied initially in 1974 with the same source, rates, and frequencies continued from May to October in 1975 and 1977.

Growing medium samples (0 to 3-inch depth) were taken periodically to determine nutrient levels. Elements other than K were applied to maintain extractable P (superphosphate) at about 200 ppm, with N (ammonium nitrate) supplied at the rate of 2 pounds monthly per 1,000 square feet from April to October.

Table 5.—Potassium treatments, April to October, 1974, 1975, and 1977

Treatment no.	Rate/application[1] (lb/1,000 ft^2)	Season of application[2]	Total/year[1] (lb/1,000 ft^2)
1	1	Spring	1
2	1	Spring and summer	2
3	1	Spring, summer, fall	3
4	3	Spring	3
5	3	Spring and summer	6
6	3	Spring, summer, fall	9
7	9	Spring	9
8	9	Spring and summer	18
9	9	Spring, summer, fall	27

[1] Available K_2O.

[2] Spring (May), summer (July), fall (September).

Results and Discussion

Nitrogen Fertilization (1974, 1975, and 1976)

Yield was correlated with turfgrass quality (r = 0.30**). Application date was also associated with quality (r = 0.19**), but not with yield. Both yield and quality were lowest in 1975 and highest in 1974 (Table 6). Peak mean quality in all years occurred on August 15 and mean quality was lowest on June 30, varying at other dates. Yields were highest on June 15 and lowest on September 10 (Table 7).

Quality was significantly higher (*) in five of the six plots treated with activated sewage sludge (Milorganite) at monthly or bimonthly frequencies. All others received lower quality ratings. Yields were also significantly higher (*) in the five Milorganite plots. Treatment with this fertilizer at all rates except 2 pounds monthly per 1,000 square feet (Treatment No. 11) resulted in the highest yields. Variable yields occurred in plots treated with other sources, rates, and frequencies (Table 8).

The N content of clippings was correlated with quality (r = 0.58**), yield (r = 0.34**), N source and pounds per 1,000 square feet (r = 0.29**), foliar P (r = 0.42**), and foliar K (r = 0.37**). There were no associations between year, sampling date, soil P, and foliar N concentration. At comparable N application rates and frequencies, Milorganite

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*Significant at the .05 level of probability.

**Significant at the .01 level of probability.

Table 6.—Influences of nitrogen treatment and year on quality and yield

Treatment no.	Panel evaluation[1]			Plot yield[2]		
	1974	1975	1976	1974	1975	1976
1	6.5	6.2	6.2	49	18	20
2	6.9	6.2	6.8	62	30	43
3	6.7	6.1	6.5	64	25	34
4	6.7	6.1	6.6	79	31	59
5	6.4	6.0	6.5	76	27	43
6	6.5	6.3	6.1	45	18	24
7	6.4	6.2	6.5	64	25	34
8	6.5	6.1	7.0	74	27	45
9	6.6	6.1	7.1	80	29	53
10	6.8	6.2	6.9	71	31	65
11	7.0	6.6	7.1	65	36	51
12	7.3	6.7	7.3	97	41	72
13	7.3	6.8	7.3	102	47	88
14	7.1	6.6	7.0	102	41	65
15	7.2	6.6	7.2	109	43	69
16	7.2	6.4	6.5	109	48	79

[1] 1-9, 9 = best.

[2] Grams fresh weight/22 ft^2.

Table 7.—Mean effects of nitrogen treatment and harvest date on quality and yield, 1974, 1975, and 1976

Treatment	Panel evaluation[1]						Plot yield[2]					
no.	June 15	June 30	July 20	Aug. 5	Aug. 15	Sept. 10	June 15	June 30	July 20	Aug. 5	Aug. 15	Sept. 10
1	5.5	6.1	6.4	6.2	7.1	6.8	51	38	21	25	28	20
2	6.3	6.3	6.5	6.3	7.0	7.0	92	53	39	31	33	31
3	6.0	6.2	6.3	6.2	7.1	6.7	76	58	30	32	37	26
4	6.6	6.4	6.2	6.1	6.8	6.7	126	59	44	44	41	34
5	6.2	6.2	6.2	6.0	6.6	6.4	95	62	36	38	41	31
6	5.5	5.9	6.4	6.7	7.1	6.9	47	38	23	30	26	18
7	5.8	6.2	6.5	6.6	7.0	6.8	65	52	39	43	33	27
8	6.2	6.3	6.4	6.5	7.0	6.8	85	56	38	45	48	34
9	6.6	6.3	6.4	6.4	7.0	7.0	101	60	45	51	45	39
10	7.0	6.6	6.3	6.2	6.9	6.9	97	61	46	47	60	42
11	6.4	6.6	6.9	6.9	7.5	7.5	73	63	42	45	53	48
12	6.8	6.9	7.0	7.0	7.3	7.7	105	95	59	56	74	57
13	7.2	6.5	7.2	7.0	7.7	7.3	101	101	81	70	73	74
14	6.5	6.2	7.3	7.0	7.5	7.3	100	88	66	73	53	60
15	6.7	6.2	7.3	7.1	7.5	7.3	97	101	71	75	63	57
16	6.4	6.2	6.7	6.5	7.0	6.5	150	84	78	52	81	44

[1] 1-9, 9 = best.

[2] Grams fresh weight/22 ft^2.

generally resulted in higher foliar N concentrations than ammonium nitrate, while plots treated with unreaformaldehyde were intermediate (Table 8). Peak mean N concentration in 1975 occurred July 20 and the lowest concentration occurred September 10, but highest amounts present in 1976 were on August 15 and September 10, and the lowest were on June 15. Mean N content of the foliage was higher in 1976 than in 1975.

Foliar P percentages were correlated with N treatment ($r = 0.22^{**}$), and with foliar N and K ($r = 0.42^{**}$ and 0.43^{**}, respectively), as shown in Table 8. There was no association between yield, quality, sampling date, soil P, and foliar P. The highest percentage of P was present in clippings from plots that received 4 pounds of Milorganite N monthly. All remaining treatments produced turfgrass with variable concentrations of P (Table 8). In 1975, the lowest foliar P concentration occurred on September 10 and the highest on July 20. Highest percentages in 1976 were on May 20 and lowest on June 30. Mean P concentration of samples was higher in 1975 than in 1976.

The amount of foliar K was correlated with treatment ($r = 0.27^{**}$), foliar N ($r = 0.39^{**}$), and foliar P ($r = 0.43^{**}$). A correlation ($r = 0.16^{*}$) also existed between the K concentration in the clippings and quality of the clippings, but there was no correlation between K concentration and yield, year, or amount of soil P. A higher percentage of K was present in foliage from plots treated monthly with 4 pounds of Milorganite N than in others

Table 8.—Mean effects of nitrogen treatment on quality, yield, and foliar concentrations of N, P, and K

	1974, 1975, 1976		1975, 1976 (% dry wt.)		
Treatment no.	Quality score[1] [3]	Yield[2] [3]	N[3]	P[3]	K[3]
13	7.2^{a}	79^{a}	5.04^{ab}	0.54^{b}	1.82^{b}
12	7.1^{ab}	70^{b}	5.12^{a}	0.57^{a}	1.91^{a}
15	7.0^{bc}	74^{ab}	4.86^{d}	0.52^{cd}	1.77^{bc}
14	6.9^{c}	69^{b}	4.72^{de}	0.52^{cd}	1.76^{bcd}
11	6.9^{c}	51^{d}	4.72^{de}	0.54^{b}	1.72^{cd}
16	6.7^{de}	78^{a}	4.67^{e}	0.50^{ef}	1.74^{bcd}
10	6.7^{de}	56^{c}	5.13^{a}	0.54^{b}	1.69^{cd}
9	6.6^{def}	54^{cd}	5.01^{b}	0.52^{cd}	1.68^{cde}
2	6.6^{def}	45^{ef}	4.78^{d}	0.51^{de}	1.72^{bcd}
8	6.5^{efg}	49^{de}	4.80^{cd}	0.52^{cd}	1.68^{cde}
4	6.5^{efg}	56^{c}	4.88^{c}	0.51^{de}	1.67^{def}
3	6.4^{fghi}	41^{g}	4.39^{g}	0.49^{fg}	1.60^{efg}
7	6.4^{fghi}	41^{g}	4.53^{f}	0.50^{ef}	1.59^{fg}
6	6.3^{hi}	29^{h}	4.10^{h}	0.49^{fg}	1.53^{g}
5	6.3^{hi}	48^{def}	4.52^{f}	0.49^{fg}	1.55^{g}
1	6.3^{hi}	29^{h}	4.17^{h}	0.49^{fg}	1.54^{g}

[1] 1-9, 9 = best.

[2] Grams fresh weight/22 ft^2.

[3] Mean separation by Duncan's multiple range test; means within columns with at least one letter in common are not different at the 5% level.

(Table 8). Highest foliar K percentage occurred on July 20 and the lowest on September 10. The mean K content of clippings was higher in 1976 than in 1975.

Copper and zinc concentrations in turfgrass foliage were interrelated (r = 0.72**) and were correlated with quality (r = 0.56** and 0.26**), yield (r = 0.43** and 0.26**), and foliar K levels (r = 0.25** and 0.41**). Treatment influenced amounts of Cu and Zn present in the tissue (Table 9). The concentration of copper in clippings was highest on September 10 and lowest on August 15. Foliar Zn amounts were highest on July 20 and lowest on June 15.

The amount of foliar Fe present was correlated with tissue P (r = 0.43**). Highest Fe content occurred in clippings from plots treated monthly with 4 pounds of N from Milorganite (Table 9). Foliar Fe was highest on the August 15 sampling date and lowest on June 15 in both 1975 and 1976.

Foliar S, Mg, and Mn concentrations were not associated with quality or yield (Table 9). Mean S content of clippings was highest at the last sampling date (September 10) and lowest on June 30. Foliar Mg was highest on August 5 and lowest on June 30. Levels of Mn present in grass foliage were variable throughout the sampling dates and years.

Yield may not necessarily be a measure of all turfgrass quality. However, this research showed that the two factors were related on 23 harvest dates and evaluations. Shoot density was reported by evaluation panel

Table 9.—Mean effects of treatment on foliar concentration of Mg, S, Fe, Mn, Cu, and Zn

	1975, 1976 (dry wt. basis)					
Treatment no.	Mg[1] (%)	S[1] (%)	Fe[1] (ppm)	Mn[1] (ppm)	Cu[2] (ppm)	Zn[2] (ppm)
1	0.13	0.46	324	66	11^{c}	35^{e}
2	0.14	0.43	433	62	9^{cd}	36^{e}
3	0.14	0.46	379	64	8^{de}	32^{e}
4	0.15	0.43	310	73	7^{de}	31^{e}
5	0.14	0.44	295	65	7^{de}	31^{e}
6	0.13	0.47	362	98	8^{de}	41^{e}
7	0.13	0.45	295	111	7^{de}	39^{e}
8	0.14	0.44	252	137	6^{e}	48^{de}
9	0.15	0.41	257	144	5^{e}	44^{de}
10	0.15	0.41	310	155	5^{e}	45^{de}
11	0.14	0.47	629	64	17^{b}	64^{d}
12	0.15	0.50	1,183	116	20^{ab}	139^{ab}
13	0.14	0.47	815	108	21^{a}	145^{a}
14	0.14	0.46	457	120	21^{a}	123^{bc}
15	0.14	0.45	414	129	19^{ab}	115^{c}
16	0.15	0.46	305	143	21^{a}	123^{bc}

[1] Not significantly different in means.

[2] Mean separation by Duncan's multiple range test; means within columns with at least one letter in common are not different at the 5% level.

members as a criterion in quality ratings, combined with texture and color of the grass. Density has been proposed as a better measurement of golf green turfgrass quality than clipping yields. High shoot density alone has also been reported as not positively associated with the quality of golf green turf. Visual rating, however, is considered the best method of turf quality evaluation if performed by competent individuals independently of one another.

Six of the eight highest yields and quality ratings resulted from treatment with activated sewage sludge. This fertilizer has been widely used on golf greens for many years. Ureaformaldehyde at the highest rate (6 pounds of N per 1,000 square feet per month) was the only other treatment that resulted in comparable yields, but it ranked significantly lower (*) in turf quality than five of the six Milorganite treatments. Ureaformaldehyde N plots generally received their highest quality scores in the spring and fall, dropping below acceptable levels in July, August, and September. Ammonium nitrate treatments, including those applied biweekly, produced results similar to those obtained with UF. Temperature and/or moisture had more influence on the N response from ammonium nitrate and UF than on the N response from Milorganite. Some other unpublished research here has shown agreement with these data concerning UF and ammonium nitrate as N sources.

Maximum daily air temperatures at the Burden Research Center turfgrass plots reached 90°F or higher in June and continued at those levels until late September or early October each year. Rainfall during the 6-month research period varied from about 34 inches in 1975 to 5.5 inches in 1976, with 19 inches received in 1974. However, all plots received at least 2 inches of moisture per week; rainfall was supplemented with irrigation when necessary. Mean quality and yield were lowest in 1975, reflecting the influence of high rainfall on the effectiveness of some of the fertilizers used in this study. The leaching effect of the large amounts of moisture in 1975 was greater on the ammonium nitrate and UF treatments than on those containing Milorganite. Furthermore, mean foliar N concentrations in clippings were higher in 1976 than in 1975.

The influence of temperature also seemed more evident on plots treated with ammonium nitrate and UF. Mean quality of the Milorganite plots was generally highest from August 15 to September 10, when temperatures were at an average seasonal maximum (90° to 95°F). Mean quality of the grass in most other treatments was also generally highest on August 15 but decreased by September 10. Results with UF and ammonium nitrate seem to agree with reported research in that the amount of applied N from these sources apparently assimilated by the turfgrass was lower than that of some other N materials, showing the effect of high temperature on N liberation. However, most published results were obtained with cool-season turfgrasses grown under lower temperature and rainfall conditions than those in this study. Research *(24)* with 'Tifgreen' bermudagrass in a somewhat similar environment disclosed that ammonium nitrate and urea treatments produced high-quality turf, while Milorganite produced higher quality turf than plots treated with other organic sources. Soluble sources were applied eight or 16 times per season, while slowly soluble sources produced more uniform growth with fewer applications. The research reported here showed that Miloganite at similar rates generally produced higher turfgrass quality than other sources used, even when applied less frequently.

A limited amount of research concerning turfgrass foliar analysis has been reported. Sampling procedures and interpretation of results have restricted use of this technique to diagnose plant nutrient status or interpret response. Seasonal fluctuations are considered to be a major source of error in foliar analyses. All tissue from a given harvest date in this study was of the same approximate maturity, since plots were not mowed during the 24-hour period preceding sampling. Levels of N used varied considerably, ranging from low rates to much larger amounts than are commonly applied. Tissue analyses reported herein were intended primarily to determine the possible influence of N source, rate, and frequency on tissue concentrations of other elements and subsequent quality and yield of the turfgrass. One N source, Milorganite, contained other elements which were not present in ammonium nitrate and UF *(25)*.

Foliar N levels in this study were somewhat higher than those previously reported *(7, 9, 19)*. Five of the six Milorganite-treated plots were of higher quality than all others, but foliar N was higher in only two. Some UF treatments resulted in higher concentrations of tissue N than several of the highest Milorganite plots, but ranked lower in quality. A few ammonium nitrate treatments showed a similar pattern. The trimonthly Milorganite plots were also of higher quality than eight others, but ranked lower than several treatments in N concentration of clippings. These data suggest that high foliar levels of N alone may not account for improved quality. Percentages of N, P, and K in the tissue were related. Foliar P concentration alone had no apparent influence on panel ratings, while the K concentration of clippings was associated with turf quality.

Foliar Cu and Zn were also related to grass quality, while Fe, Mg, Mn, and S were not. Treatments that received panel evaluations above the acceptable level of 6.5 also generally had higher amounts of N, P, Cu, and Zn in clippings.

The mean Zn content of foliage was highest in plots treated with Milorganite, which contained significant amounts of this element (1,200 to 1,500 ppm). Topsoil used in the medium was considered low in extractable Zn, containing less than 1 ppm. Foliar analyses from all plots showed higher concentrations of Zn than that reported by others.

Copper was also highest in tissue samples from the Milorganite-treated plots. This fertilizer contained from 400 to 470 ppm of Cu by analysis. However, the concentration of this element present in clippings was about the same as that previously reported, while the Mn concentration was generally lower. Extractable Cu and Mn in the topsoil used was considered low, less than 1 and 19 ppm, respectively.

The average Fe concentration was also generally highest in foliage from plots treated with Milorganite, which contained from 3.9 to 6.4 percent Fe. Tissue samples from all treatments had higher concentrations of Fe than had been indicated in limited research. Seasonal variations in foliar Fe occurred, but no Fe deficiency symptoms were observed at any time during this study. Topsoil used was considered high in extractable Fe, from 49 to 66 ppm, and could account for the lack of an association between this element in the foliage and observed quality. Some data have shown that the addition of Fe improved turfgrass quality on soils where the element was present in amounts usually considered adequate *(23)*.

Concentrations of Mg in the tissue were lower than those reported elsewhere *(9, 20)*, but no observable deficiency symptoms occurred in the grass on any plot. Analysis *(25)* showed from 0.29 to 0.42 percent Mg present in Milorganite. However, no foliar samples contained significantly higher amounts of this element than others.

Foliar S concentrations did not vary significantly with treatment, even though Milorganite fertilizer contained from 0.99 to 1.50 percent of this element. The tissue S concentration of 0.43 to 0.50 percent (dry weight) found in this study would be above the reported critical level of 0.1 to 0.2 percent for some turfgrasses *(20)*. No S deficiency was observed in the grass of any plot during 1975 or 1976.

Nitrogen Fertilization (1977 and 1978)

Quality was not associated with yield, but was related to amounts of foliar N (r = 0.42**), K (r = 0.29**), Cu (r = 0.65**), and Zn (r = 0.44**). Yield was correlated with the foliar N (r = 0.42**) and P (r = 0.22*) content only. Application date and treatment significantly affected (**) quality and yield, with a highly significant interaction between date and treatment. No significant yearly difference in quality occurred between the 1977 and 1978 seasons, but yields were higher in 1978 than in 1977 (Table 10). Highest mean quality (five common harvests) occurred on the August 5 date and the lowest in July. Yields were highest in June and lowest in August (Table 13).

Quality was significantly higher in the plots treated with activated sewage sludge (Milorganite) than all others, regardless of rate or application frequency (Table 12). Yields were largest in two of the six Milorganite plots and were higher in two other Milorganite plots than any except those treated with 12 pounds of IBDU N per 1,000 square feet monthly, which had some of the lowest quality ratings. The low evaluation scores of

IBDU-treated plots (Table 12), compared with those of plots treated with other fertilizers in this study, were primarily due to the phytotoxic influence of IBDU on the turfgrass. All rates of IBDU above 2 pounds of N resulted in some grass injury, generally increasing with the amount applied. This damage seemed to occur first on roots of the turfgrass and began to appear on the foliage about 2 weeks following application, even though all N sources (including IBDU) were watered in with a hand sprinkler immediately after they were applied. Plots treated with ammonium nitrate were of intermediate quality in comparison with plots treated with other sources used in this study, as was the case in the N research conducted during 1974, 1975, and 1976.

These results generally substantiate those obtained in the study conducted from 1974 to 1977 with Milorganite, ammonium nitrate, and UF. Quality of the grass in plots treated with Milorganite was significantly higher (*) than that in others during 1977 and 1978, as was the case in the 1974 to 1977 research. The influences of moisture and/or temperature on turfgrass quality when treated with fertilizers other than Milorganite seemed as evident in this study as in the research previously described. Apparently, the amounts of some applied elements from inorganic fertilizer sources that were assimilated by the grass plant were lower than those supplied by Milorganite, which could account for quality difference in turfgrasses *(2)*.

The N content of clippings was influenced by treatment and application date, although two of the IBDU plots with the highest percentages of foliar N (Nos. 9 and 10) had the lowest quality ratings. This was partially due to the phytotoxic effects of the high rates of IBDU on the turfgrass, but also to lower concentrations of some other elements in the grass foliage (Table 12) which seem associated with quality *(2)*. Foliar N concentration alone was not as highly associated with quality in this portion of the N research as it was in the earlier study. However, quality was generally higher as amounts of all elements in the grass clippings except P increased above certain levels (in the Milorganite-treated plots, Nos. 11 through 16). The amount of N in grass clippings was higher in 1977 than in 1978, although rainfall during the growing season was about the same each year (36.4 and 35.5 inches, respectively), as shown in Table 10.

Foliar N was generally highest in the Milorganite-treated plots in 1977, except for IBDU treatments Nos. 9 and 10, where quality ratings were generally lowest during both years in which this research was conducted. However, mean levels of N in the grass foliage (1977 and 1978) were greatest on the August 5 sampling date, when average quality ratings were also highest, which was similar to results reported during previous years *(18)*. Lowest mean foliar N concentrations in 1977 and 1978 occurred in July, when turfgrass average quality was also lowest, as in 1975 and 1976.

Percentages of foliar P were influenced by treatment and application date, with a highly significant interaction existing between treatment and date. Plots treated with 4 pounds of Milorganite monthly (Treatment No. 12) contained significantly (*) higher amounts of P in clippings than all others, while plots on which ammonium nitrate was applied were generally lowest in this element (Table 12). It should be pointed out that treatment with IBDU resulted in generally higher levels of foliar P than all others, with the exception of the 4-pounds-per-month rate of Milorganite, although only the Milorganite fertilizer contained P *(25)*. However, additional P was added to all plots periodically from superphosphate to maintain extractable soil P levels at about 300 ppm. Mean concentrations of this element in grass clippings (all treatments and sampling dates) were the same in 1977 and 1978, although slight variations occurred among treatments (Table 10). Treatment No. 12, however, was highest in foliar P during both years (Table 11).

Levels of foliar P in 1977 were highest on the September 15 and lowest on the July 15 sampling dates. In 1978, however, the reverse occurred. Variability also existed during 1975 and 1976. Fluctuations in tissue concentrations of this element among treatments and dates were larger in 1975 and 1976 than in the 1977 and 1978 seasons. Sampling error due to differences in tissue maturity and seasonal variations could influence these results, according to some authorities *(9)*. However, age of the tissue sampled was not considered to be a factor in the research reported here, as

Table 10.—Effect of treatment and year on quality, yield, and foliar concentrations of N, P, and K

Treatment no.	Panel evaluation[1]		Plot yield[2]		Foliar N (%)		Foliar P (%)		Foliar K (%)	
	1977	1978	1977	1978	1977	1978	1977	1978	1977	1978
1	6.6	6.6	48	55	4.5	3.9	0.47	0.48	1.7	1.6
2	6.1	6.3	47	75	4.5	4.0	0.48	0.49	1.7	1.6
3	6.1	6.2	47	85	4.6	3.9	0.49	0.46	1.8	1.6
4	5.8	6.2	53	117	4.6	4.3	0.50	0.52	1.8	1.8
5	5.9	6.2	49	87	4.5	4.2	0.49	0.51	1.8	1.7
6	6.0	6.0	78	117	5.1	4.7	0.57	0.56	2.0	1.8
7	5.6	6.2	76	110	5.1	4.4	0.56	0.54	2.0	1.8
8	5.8	6.4	88	135	5.2	4.5	0.58	0.52	2.0	1.8
9	5.5	6.2	107	145	5.4	4.7	0.59	0.56	2.0	1.9
10	5.3	4.9	96	124	5.5	4.9	0.60	0.55	1.9	1.7
11	7.2	6.8	83	107	5.0	4.1	0.51	0.60	2.0	1.8
12	7.5	6.7	109	143	5.4	4.5	0.56	0.64	2.2	1.9
13	7.2	6.8	102	128	5.0	4.2	0.52	0.53	2.1	1.9
14	7.3	6.7	123	147	5.3	4.4	0.55	0.53	2.2	2.1
15	7.2	6.8	125	177	5.2	4.3	0.54	0.50	2.1	2.0
16	7.4	6.3	121	203	5.3	4.4	0.54	0.53	2.2	2.0

[1] 1-9, 9 = best.

[2] Grams fresh weight/22 ft^2.

discussed in Experimental Procedure. Some other possible explanations are suggested in the P research section of this publication, along with seasonal variations.

Table 11.—Influence of treatment and year on foliar levels of Cu, Fe, and Zn

Treatment na.	Element (ppm)					
	Cu		Fe		Zn	
	1977	1978	1977	1978	1977	1978
1	11	13	21	24	35	48
2	9	11	24	28	36	46
3	7	10	25	23	32	44
4	6	8	19	19	31	44
5	7	15	20	20	31	43
6	8	8	20	20	41	52
7	6	8	18	19	39	48
8	5	7	21	18	48	52
9	5	8	19	18	44	49
10	4	8	19	19	45	46
11	17	27	22	24	64	102
12	20	41	26	31	139	152
13	21	19	29	28	145	99
14	21	20	26	29	123	115
15	20	21	35	27	118	135
16	21	30	42	38	123	163

Table 12.—Mean effects of treatment on quality, yield, and foliar nutrient concentrations, six harvest dates per year, 1977 and 1978

Treatment na.	Quality[1]	Yield[2]	Faliar N	Faliar P	Faliar K	Foliar Cu	Faliar Fe	Faliar Zn
			(%)			(ppm)		
12	7.1^{a}[3]	126^{b}	5.0^{bc}	0.60^{a}	2.0^{a}	31^{a}	29^{c}	146^{a}
15	7.0^{a}	151^{a}	4.8^{de}	0.52^{fg}	2.1^{a}	21^{c}	31^{b}	127^{b}
14	7.0^{a}	135^{b}	4.9^{d}	0.54^{e}	2.1^{a}	21^{c}	28^{cd}	119^{bc}
13	7.0^{a}	115^{c}	4.6^{ef}	0.53^{f}	1.9^{bc}	20^{cd}	29^{c}	122^{bc}
11	7.0^{a}	95^{d}	4.6^{ef}	0.56^{cd}	1.9^{bc}	22^{c}	23^{def}	83^{c}
16	6.9^{a}	162^{a}	4.9^{cd}	0.54^{e}	2.1^{a}	26^{b}	40^{a}	143^{a}
1	6.6^{b}	52^{g}	4.2^{hi}	0.48^{h}	1.7^{de}	12^{e}	23^{def}	42^{e}
3	6.2^{bc}	66^{fg}	4.3^{gh}	0.48^{h}	1.7^{de}	9^{e}	24^{def}	38^{e}
2	6.2^{bc}	61^{fg}	4.3^{gh}	0.49^{h}	1.7^{de}	10^{e}	26^{de}	41^{e}
8	6.1^{bc}	112^{cd}	4.9^{cd}	0.55^{d}	1.9^{bc}	6^{h}	20^{ef}	50^{d}
5	6.1^{bc}	68^{b}	4.4^{g}	0.50^{h}	1.8^{cd}	11^{e}	20^{ef}	37^{ef}
6	6.0^{de}	97^{d}	4.9^{cd}	0.57^{bc}	1.9^{bc}	8^{f}	20^{ef}	47^{d}
4	6.0^{de}	85^{e}	4.5^{g}	0.51^{gh}	1.8^{cd}	7^{fg}	19^{ef}	38^{e}
9	5.9^{de}	126^{b}	5.1^{b}	0.58^{b}	1.9^{bc}	7^{fg}	19^{ef}	47^{d}
7	5.9^{de}	93^{d}	4.8^{de}	0.55^{d}	1.9^{bc}	7^{fg}	19^{ef}	44^{e}
10	5.2^{f}	110^{cd}	5.2^{a}	0.58^{b}	1.8^{cd}	6^{h}	19^{ef}	45^{d}

[1] 1-9, 9 = best.

[2] Grams fresh weight/22 ft^2.

[3] Mean separation by Duncan's multiple range test; means within columns with at least ane letter in camman are nat different at the 5% level.

Table 13.—Mean influences of treatment and harvest date on quality and yield, five common harvest and evaluation dates, 1977 and 1978

Treatment no.	Panel evaluation[1]					Plot yield[2]				
	June 15	July 15	Aug. 5	Aug. 20	Sept. 15	June 15	July 15	Aug. 5	Aug. 20	Sept. 15
1	6.3	6.8	7.0	6.5	6.7	62	59	68	28	41
2	6.8	6.4	6.6	5.7	6.2	68	72	82	30	49
3	6.2	6.4	7.0	5.4	6.2	74	89	99	37	69
4	7.5	6.6	6.1	4.6	5.7	87	148	114	31	58
5	6.3	5.9	7.1	5.7	5.7	54	55	119	41	70
6	6.7	5.8	6.4	5.3	5.8	123	149	125	36	66
7	6.5	5.7	6.4	5.5	5.7	128	150	109	33	53
8	6.9	5.5	6.5	5.5	5.9	154	216	118	34	50
9	6.7	5.3	6.3	5.4	5.9	209	231	91	42	87
10	4.8	5.6	6.2	4.7	4.7	189	198	97	34	63
11	6.4	7.0	7.6	7.5	6.9	125	72	122	56	91
12	6.9	6.7	7.4	7.2	7.1	178	168	132	74	89
13	7.1	6.0	7.5	7.5	7.2	183	126	148	52	70
14	6.7	6.1	7.3	6.9	7.6	225	145	161	61	88
15	7.1	5.9	7.3	7.7	7.3	257	249	66	92	117
16	7.1	5.6	7.0	7.9	7.1	244	297	86	88	151

[1] 1-9, 9 = best.

[2] Grams fresh weight/22 ft^2.

Foliar K levels were influenced by treatment. A highly significant interaction also existed between the treatment and date of application. Four of the six plots treated with Milorganite had higher concentrations of K in clippings than all others (Table 12). This fertilizer was the only source, however, that contained K *(25)*, but supplemental K (potassium chloride) was added to all plots periodically to maintain levels of extractable K at about 100 ppm. The amounts of the element in grass foliage from plots treated with other fertilizers showed no significant variations. Foliar K concentrations were higher in this research than those reported in 1975 and 1976 on the same golf greens *(2)*, but the differences in 1977 and 1978 (Table 11) were not significant, probably because rainfall during both seasons was about the same. Highest foliar K levels in 1977 occurred on September 15 and lowest on July 15, but in 1978 the concentrations of this element were highest on June 15, and were lowest on September 15.

The amounts of Cu, Fe, and Zn in grass clippings (Tables 11 and 12) were significantly influenced (*) by fertilizer treatment, with a strong interaction occurring between treatment and application date (**). Plots treated with Milorganite were all significantly higher (*) than the other plots in concentrations of these elments. Milorganite fertilizer was the only source that contained Cu, Fe, and Zn (approximately 420 ppm, 4 to 6 percent, and 1,440 ppm, respectively). Foliar content of two of these elements (Cu and Zn) influenced quality of the turfgrass in the 1975 and 1976 research. All Milorganite plots were significantly higher (*) than other treatments in quality, and in amounts of Cu, Fe, and Zn present in clippings, in this (1977 and 1978) study.

The above results, as in 1975 and 1976, suggest that high levels of foliar N alone do not seem to account for improved grass quality. Although foliar P concentrations were not associated with quality, they were related to yield. However, the amounts of K, Cu, Fe, and Zn, along with N, did affect quality of the turfgrass in the research conducted from 1974 through 1978.

Nitrogen Fertilization (1979 and 1980)

Experimental data showed turfgrass quality was significantly higher (*) in samples from five of the six Milorganite treatments than in all others (Tables 3 and 14). The lowest quality occurred when SCU, Milorganite, and Hi-Organic fertilizers were applied at the rate of 1 pound of N monthly and SCU and Hi-Organic at 2 pounds of N bimonthly per 1,000 square feet. Treatments receiving the largest amounts of SCU and Hi-Organic still produced significantly lower (*) quality turfgrass than all Milorganite plots except one (1 pound of N monthly), even those treated with lower or equal rates of Milorganite N.

Yields were not associated with quality, being higher in only three of the Milorganite treatments that received the largest amounts of total N per season. Most other plots produced somewhat variable turfgrass yields (Table 14).

Table 14.—Mean effects of treatment on quality, yield, and foliar nutrient concentrations, 1979 and 1980

Treatment no.	Quality[1]	Yield[2]	Foliar N	Foliar P	Foliar K	Foliar Cu	Foliar Fe	Foliar Zn
			-------------	(%)	-------------	------------	(ppm)	------------
16	7.4^{a}[3]	45^{a}	5.0^{a}	0.52^{a}	2.2^{a}	26^{a}	24^{a}	188^{a}
13	7.2^{ab}	45^{a}	4.5^{bc}	0.48^{cd}	1.8^{bc}	20^{bc}	15^{d}	104^{b}
12	6.9^{c}	44^{a}	4.6^{bc}	0.50^{b}	1.9^{bc}	21^{b}	15^{d}	87^{c}
15	6.9^{c}	35^{b}	4.7^{b}	0.49^{bc}	1.8^{bc}	23^{ab}	17^{b}	115^{b}
14	6.7^{cd}	28^{de}	4.4^{d}	0.48^{cd}	1.9^{bc}	21^{b}	14^{e}	89^{c}
10	6.4^{ef}	29^{d}	5.1^{a}	0.52^{a}	1.8^{bc}	17^{d}	13^{f}	38^{fg}
4	6.4^{ef}	26^{de}	4.7^{b}	0.50^{b}	2.0^{b}	14^{e}	12^{fg}	30^{gh}
7	6.3^{efg}	36^{b}	4.4^{d}	0.49^{bc}	1.7^{bcd}	17^{d}	11^{g}	38^{fg}
9	6.3^{efg}	22^{e}	4.7^{b}	0.48^{cd}	1.6^{d}	16^{de}	10^{hi}	35^{fg}
2	6.2^{fgh}	34^{bc}	4.6^{bc}	0.51^{a}	1.8^{bc}	16^{de}	16^{cd}	36^{fg}
6	6.2^{fgh}	21^{ef}	4.3^{de}	0.48^{cd}	1.7^{bcd}	15^{e}	15^{d}	23^{i}
8	6.0^{hi}	15^{h}	4.3^{de}	0.45^{ef}	1.6^{d}	17^{d}	11^{g}	29^{h}
11	5.9^{hi}	18^{g}	4.0^{f}	0.47^{d}	1.6^{d}	17^{d}	14^{e}	64^{d}
3	5.8^{i}	16^{h}	4.3^{de}	0.46^{de}	1.7^{bcd}	15^{e}	10^{hi}	54^{de}
5	5.6^{ij}	32^{bc}	3.8^{g}	0.43^{g}	1.5^{e}	19^{cd}	9^{i}	25^{i}
1	5.5^{ij}	18^{g}	4.0^{f}	0.45^{ef}	1.5^{e}	17^{d}	12^{fg}	46^{f}

[1] 1-9, 9 = best.

[2] Grams fresh weight/22 ft^2.

[3] Mean separation by Duncan's multiple range test; means within columns with at least one letter in common are not different at the 5% level.

It should be noted that turfgrass plots on which SCU was applied were generally equal in quality to those receiving Hi-Organic fertilizer at the same or higher rates (as in Treatments 4 and 10). In previous research reported here (1974 to 1979), all inorganic or synthetic organic N fertilizers generally produced inferior quality turfgrass when compared with Milorganite, an activated sewage sludge of natural organic nature. Hi-Organic is also a sewage sludge similar to Milorganite in origin, but it failed to produce turfgrass of quality equal to that of Milorganite in this study.

The complete analysis of Milorganite has been reported *(25)*. Similar chemical determinations *(18)* of Hi-Organic fertilizer in 1981 showed that it contained the following amounts of some necessary elements for turfgrasses: N, 4.70 percent; P, 1.60 percent; K, 0.53 percent; Ca, 0.62 percent; Mg, 0.21 percent; Fe, 4 percent; and Cu, Mn, and Zn, 380, 400, and 690 ppm, respectively. Analyses of Milorganite (1980) for the above elements showed: N, 6.25 percent; P, 2.40 percent; K, 0.32 percent; Ca, 0.69 percent; Mg, 0.32 percent; Fe, 6.40 percent; and Cu, Mn, and Zn, 405, 180, and 1,440 ppm, respectively. Thus, on a percentage basis, Milorganite had more N (34 percent), P (50 percent), Cu (79 percent), Fe (50 percent), Mg (52 percent), and Zn (109 percent), but less K (40 percent) and Mn (55 percent).

A comparison of SCU, Hi-Organic, and Milorganite at the rate of 2 pounds of N per 1,000 square feet on the bimonthly frequency (6 pounds of N per growing season; Treatments 3, 8, and 14) points out a significant (*) quality improvement with the use of Milorganite over both Hi-Organic and SCU sources. This amount of N is lower than that used by many golf turf managers, yet it improved quality significantly (*) over all other sources and rates in this research except for the two highest Milorganite treatments (Nos. 13 and 16), where 18 pounds of total N were applied per growing season (Tables 3 and 14). Treatment with SCU, Hi-Organic, and Milorganite at the rate of 1 pound of N per month, or 6 pounds of total N per season (Nos. 1, 5, and 11), resulted in the lowest quality turfgrass, indicating this rate in a single application did not produce acceptable golf green turfgrass based on the sources of N used in this study. Similar results were obtained with ammonium nitrate and UF at the rate of 1 pound of N per month in 1974, 1975, and 1976. Foliar nutrient levels in this research were generally lower than those during 1974 to 1979, since smaller amounts of fertilizer were applied in 1979 and 1980 to determine minimum application rates. The only plots that showed significantly (*) larger amounts of the six elements measured in clippings (N, P, K, Cu, Fe, and Zn) than all other treatments were those receiving the highest rate of Milorganite, Treatment No. 16 (Tables 3 and 14). However, the five Milorganite treatments that produced turfgrass of significantly (*) higher quality than all others, including Treatment No. 14 (6 pounds of total N per season), also contained significantly (*) higher amounts of Cu and Zn in clippings. These results are consistent with those obtained in the research from 1974 to 1979, except for use of the rate of 6 pounds of total N per 1,000 square feet, which was applied only in 1979 and 1980. Applications at this rate and frequency, using SCU and Hi-Organic sources, resulted in some of the lowest turfgrass quality ratings and foliar nutrient concentrations.

Phosphorus Fertilization (1976, 1977, and 1978)

Turfgrass yield and quality were slightly associated (r = 0.32**), although applied and total available (applied plus extractable) P, K, and applied N had no relationship with quality (Table 16). Since shoot density has been proposed as a measure of golf green turfgrass quality, these data seem in agreement, as yield was influenced by applied N-P-K and total available K. Visual ratings are considered the best method of turf quality evaluation, if performed by competent individuals independently of one another *(4)*. Shoot density has been one of the three criteria used in quality ratings *(2, 16)*.

Yield was somewhat influenced by applied N and P (r = 0.26**) and K (r = 0.30**), but not by total available P. Treatments with the highest rates of P, but constant amounts of N and K, generally resulted in higher yields. Extractable P or K in the medium were not associated with yield or quality (Tables 15 and 16). The fact that extractable P and K were not related to yield or quality, while the rate of applied fertilizer and year of application had a significant effect (**) on yield, although quality was influenced only by year, should be noted. Only treatment with the highest rates of N-P-K resulted in significant (*) yield increases, while quality was related only to the highest P level in the ratio.

Soil analysis methods appear to have influenced the results reported here. Techniques used and/or methods in which findings are expressed vary widely, and have considerable influence on the values obtained. This research shows there was no relationship between the level of extractable soil P and plant responses, while extractable soil K was associated with yield ($r = 0.16^{*}$) and foliar N concentration ($r = 0.23^{*}$). The fact that applied N-P-K influenced yield, but extractable P and K had little or no effect on yield or quality, may lead to speculation as to what constitutes total available nutrients (extractable plus applied), based on soil analyses. Foliar concentration appears to be a more reliable index of plant nutrient status in this research, since levels of N, P, and K in the foliage were correlated with yield, and some applied nutrients influenced yield and foliar nutrient amounts, including that of P, while total and available P in the medium had no association with foliar P.

Table 15.—Mean effects of extractable, applied, and total available P on yield and quality, 1976, 1977, and 1978

			P per 1,000 ft^2 per year	Soil test P, 0 to 3-inch depth	P per 1,000 ft^2 per year
Treatment no.	Yield[1]	Quality[2]	Applied	Extractable	Total available
			(ppm)		
A-5	42.5^{a}[3]	6.1^{ab}	77	46	123
B-5	41.8^{ab}	6.1^{ab}	77	176	253
C-6	41.7^{ab}	6.2^{a}	154	370	524
A-6	41.3^{abc}	5.9^{abc}	154	61	215
B-6	41.1^{abc}	5.9^{abc}	154	203	357
B-4	40.3^{abc}	5.8^{bc}	39	161	200
C-5	37.2^{bc}	5.9^{abc}	77	304	381
C-4	37.2^{bc}	5.8^{bc}	39	288	327
A-4	37.0^{c}	5.7^{c}	39	36	75
A-3	32.0^{d}	6.1^{ab}	77	48	125
C-3	31.5^{de}	5.9^{abc}	77	313	390
C-2	31.1^{de}	6.0^{abc}	39	312	351
A-2	29.0^{de}	5.9^{abc}	39	37	76
B-1	29.0^{de}	5.8^{bc}	19	165	184
B-3	28.3^{de}	6.1^{ab}	77	196	273
B-2	28.1^{de}	5.9^{abc}	39	166	205
A-1	27.2^{de}	5.9^{abc}	19	33	52
C-1	27.0^{e}	5.8^{bc}	19	283	302

[1] Grams fresh weight/22 ft^2.

[2] 1-9, 9 = best.

[3] Mean separation by Duncan's multiple range test; means within columns with at least one letter in common are not different at the 5% level.

Table 16.—Mean effects of extractable, applied, and total available P on yield, quality, and foliar nutrient concentration, 1976, 1977, and 1978

Treatment no.	Yield[1]	Turfgrass quality[2]	Foliar nutrient concentrations				(Soil test, 0 to 3-inch depth) Extractable		Applied			Total available	
			N[3]	P[3]	K[3]	Fe[3]	P	K	N	P	K	P	K
			------------(%)------------		----	(ppm)	------ (ppm) ------		----(kg/yr/100 m^2)[4]----			--(kg/yr/100 m^2)[4]--	
A-5	42.5^{a}[5]	6.1^{ab}	4.46^{a}	0.51^{cd}	1.81^{a}	21^{a}	46	86	8.72	1.90	3.63	3.90	5.42
B-5	41.8^{ab}	6.1^{ab}	4.56^{a}	0.52^{bc}	1.80^{a}	15^{c}	176	70	8.72	1.90	3.63	4.59	5.12
C-6	41.7^{ab}	6.2^{a}	4.53^{a}	0.52^{bc}	1.77^{a}	16^{bc}	370	84	8.82	3.79	3.63	9.27	5.38
A-6	41.3^{abc}	5.9^{abc}	4.57^{a}	0.54^{a}	1.82^{a}	17^{b}	61	87	8.72	3.79	3.63	7.59	5.46
B-6	41.1^{abc}	5.9^{abc}	4.56^{a}	0.53^{ab}	1.83^{a}	15^{c}	203	69	8.72	3.79	3.63	8.36	5.08
B-4	40.3^{abc}	5.8^{bc}	4.54^{a}	0.51^{cd}	1.80^{a}	16^{bc}	161	69	8.72	0.96	3.63	2.68	5.08
C-5	37.2^{bc}	5.9^{abc}	4.52^{a}	0.51^{cd}	1.78^{a}	16^{bc}	304	83	8.72	1.90	3.63	5.27	5.38
C-4	37.2^{bc}	5.8^{bc}	4.48^{a}	0.51^{cd}	1.78^{a}	15^{c}	288	84	8.72	0.96	3.63	3.41	5.38
A-4	37.0^{c}	5.7^{c}	4.48^{a}	0.49^{fg}	1.80^{a}	16^{bc}	36	87	8.72	0.96	3.63	2.00	5.46
A-3	32.0^{d}	6.1^{ab}	4.33^{b}	0.50^{de}	1.70^{b}	17^{b}	48	83	4.36	1.90	1.82	3.41	3.56
C-3	31.5^{de}	5.9^{abc}	4.31^{bc}	0.50^{de}	1.69^{b}	15^{c}	313	78	4.36	1.90	1.82	5.36	3.45
C-2	31.1^{de}	6.0^{abc}	4.23^{bc}	0.49^{fg}	1.65^{bc}	15^{c}	312	79	4.36	0.96	1.82	3.50	3.48
A-2	29.0^{de}	5.9^{abc}	4.28^{bc}	0.49^{fg}	1.63^{bc}	19^{b}	37	83	4.36	0.96	1.82	2.00	3.56
B-1	29.0^{de}	5.8^{bc}	4.21^{bc}	0.48^{gh}	1.63^{bc}	16^{bc}	165	65	4.36	0.48	1.82	1.82	3.04
B-3	28.3^{de}	6.1^{ab}	4.26^{bc}	0.50^{de}	1.66^{bc}	16^{bc}	196	68	4.36	1.90	1.82	4.73	3.25
B-2	28.1^{de}	5.9^{abc}	4.18^{c}	0.48^{gh}	1.65^{bc}	16^{bc}	166	67	4.36	0.96	1.82	2.73	3.22
A-1	27.2^{de}	5.9^{abc}	4.20^{bc}	0.47^{hi}	1.60^{c}	17^{b}	33	87	4.36	0.48	1.82	1.09	3.63
C-1	27.0^{e}	5.8^{bc}	4.25^{bc}	0.48^{gh}	1.60^{c}	15^{c}	283	78	4.36	0.48	1.82	2.45	3.45

[1] Grams fresh weight/22 ft^2.

[2] 1-9, 9 = best.

[3] Dry weight basis.

[4] 1 kg = 2.2 lbs.; 100 m^2 = 1,080 ft^2.

[5] Mean separation by Duncan's multiple range test; means within columns with at least one letter in common are not different at the 5% level.

Yield was correlated with foliar N (r = 0.46**), P (r = 0.32**), K (r = 0.44**), and Fe (r = 0.14*) concentrations (Table 16). Foliar N concentration was affected by year and rate of N-P-K application, and correlated with the amount of foliar P (r = 0.65**), K (r = 0.69**), and Fe (r = 0.29**). Application of the highest rate (100 pounds per 1,000 square feet per season) of all three fertilizer ratios resulted in the highest percentage of foliar N (Table 16). Lowest foliar N levels occurred in 1976, when evaluation scores were highest and yields were intermediate. The highest foliar N occurred in 1977, when yields were also greatest (Tables 17 and 18). Foliar N amounts were highest in August and lowest on the May harvest dates.

The levels of foliar P were influenced by year and fertilizer rate. Total available P in the medium and foliar P concentration were not associated, but the highest amounts of applied P resulted in the largest accumulation of this element in the foliage (Tables 16 and 18). Foliar P was correlated with foliar K and Fe (r = 0.59** and r = 0.39**, respectively). Lowest foliar P occurred in 1976, with levels remaining relatively constant in other years (Table 18). The accumulation of P in clippings was highest in August and lowest on the July harvest dates.

The amounts of K in the turfgrass leaves and total available K were associated (Table 16). Significantly higher levels (*) occurred in clippings

Table 17.—Influence of treatment and year on yield and quality

Treatment	Yield[1]			Quality[2]		
no.	1976[3]	1977[4]	1978[5]	1976[3]	1977[4]	1978[5]
A-1	23.3	36.9	21.4	6.1	5.9	5.7
A-2	22.2	40.0	23.8	6.1	5.8	5.9
A-3	24.2	42.9	28.8	5.9	6.2	6.1
A-4	36.4	45.5	28.0	6.2	5.6	5.2
A-5	40.0	47.7	40.0	6.4	6.6	5.3
A-6	39.0	46.8	38.3	6.4	6.1	5.3
B-1	27.0	39.9	20.2	6.1	6.0	5.3
B-2	24.0	40.1	20.3	6.1	5.9	5.7
B-3	21.6	38.2	25.1	6.2	6.1	5.9
B-4	43.1	47.7	30.3	6.1	5.8	5.6
B-5	41.4	50.3	33.7	6.4	6.0	5.8
B-6	38.5	48.2	36.7	6.3	5.9	5.6
C-1	22.2	36.3	22.2	6.1	6.0	5.5
C-2	26.0	40.5	26.8	6.0	5.9	6.0
C-3	21.0	45.5	28.1	6.0	5.7	5.8
C-4	33.9	46.7	31.0	6.3	5.5	5.5
C-5	35.7	45.9	30.3	6.5	5.9	5.2
C-6	40.0	45.2	40.3	6.2	6.3	5.9

[1] Grams fresh weight/22 ft^2.

[2] 1-9, 9 = best.

[3] Rainfall (April 15-Sept. 30) = 4.6 inches.

[4] Rainfall (April 15-Sept. 30) = 35.0 inches.

[5] Rainfall (April 15-Sept. 30) = 33.9 inches.

Table 18.—Influence of treatment and year on foliar nutrient concentrations

Treatment	% faliar N[1]			% faliar P[1]			% faliar K[1]			ppm faliar Fe[1]		
na.	1976[2]	1977[3]	1978[4]	1976[2]	1977[3]	1978[4]	1976[2]	1977[3]	1978[4]	1976[2]	1977[3]	1978[4]
A-1	3.94	4.42	4.31	0.43	0.48	0.49	1.46	1.80	1.58	23	22	28
A-2	4.00	4.50	4.39	0.44	0.50	0.52	1.51	1.88	1.55	26	23	31
A-3	3.93	4.59	4.53	0.45	0.53	0.54	1.57	1.89	1.68	23	22	28
A-4	4.35	4.63	4.51	0.46	0.51	0.52	1.74	1.98	1.70	21	21	26
A-5	4.28	4.64	4.50	0.46	0.53	0.55	1.71	1.95	1.80	47	25	35
A-6	4.27	4.75	4.75	0.48	0.56	0.58	1.65	2.04	1.82	25	22	26
B-1	3.98	4.49	4.22	0.44	0.50	0.50	1.55	1.81	1.57	21	20	26
B-2	3.91	4.45	4.24	0.44	0.50	0.52	1.54	1.80	1.64	23	19	27
B-3	3.92	4.50	4.46	0.44	0.51	0.54	1.55	1.86	1.61	24	20	25
B-4	4.37	4.72	4.58	0.47	0.53	0.53	1.75	1.97	1.72	23	20	25
B-5	4.37	4.73	4.64	0.48	0.54	0.54	1.78	1.98	1.67	20	21	23
B-6	4.30	4.77	4.68	0.47	0.56	0.57	1.73	2.04	1.74	20	21	24
C-1	4.00	4.39	4.38	0.44	0.50	0.50	1.50	1.76	1.58	22	20	24
C-2	3.92	4.45	4.42	0.44	0.50	0.53	1.53	1.85	1.62	20	21	24
C-3	3.88	4.60	4.52	0.44	0.52	0.54	1.56	1.93	1.64	21	21	24
C-4	4.23	4.61	4.67	0.46	0.52	0.53	1.68	1.93	1.76	21	21	23
C-5	4.30	4.70	4.61	0.48	0.53	0.55	1.71	1.96	1.72	21	22	24
C-6	4.27	4.69	4.71	0.47	0.54	0.55	1.70	1.97	1.68	20	21	25

[1] Dry weight basis.

[2] Rainfall (April 15-Sept. 30) = 4.6 inches.

[3] Rainfall (April 15-Sept. 30) = 35.0 inches.

[4] Rainfall (April 15-Sept. 30) = 33.9 inches.

from those plots treated with larger amounts of this element (A, B, and C; 4, 5, and 6). The year of application also affected levels of foliar K (Table 18). Concentrations in clippings were highest in 1977, while varying in other years. Largest amounts were found in the grass foliage in August and the lowest amounts on the July and September harvest dates.

Foliar Fe concentrations were affected by the year of application, being highest in 1978 but variable in 1976 and 1977 (Table 18). An interaction (**) occurred among Fe in clippings, year, and extractable soil P levels, and also between year and amount of extractable soil P (Tables 16 and 18). The extractable soil P levels and foliar Fe concentrations were somewhat related (Table 16). Amounts of Fe in clippings were highest in samples from the May harvest dates and lowest in September analyses.

The correlation shown here between foliar N, P, and K has been previously reported *(2)*. Other research has indicated that turfgrass yield and foliar N, P, and K content were related, but that amounts of extractable P in the medium were variable and unrelated to yield or quality *(3)*. Environmental influences on foliar N concentrations were also similar to those reported here, including yearly and monthly variations. Turfgrass quality fluctuated with rainfall extremes, as did foliar N levels, and both were also influenced by high temperature and/or organic matter content of the medium.

Since foliar P levels were related to yield in this study, and applied P influenced the amount of the element in clippings, some interrelationship between applied P and yield did exist. The highest rates applied—8 and 16 pounds of P_2O_5 per 1,000 square feet—generally had the largest influence on yield, and 2 pounds per 1,000 square feet had the least influence. Results were somewhat variable with the 4-pound rate. Total available P, however, did not follow a similar pattern as some of the highest yields occurred when total available P was lowest, while the reverse also occurred (Table 15).

The distinction between applied and total available P seemed to be an influencing factor in this research. Further studies are necessary before this matter can be completely resolved. For the present, however, it appears that the portion of total available P called extractable P has very little bearing on either yield or quality of 'Tifgreen' bermudagrass. On the other hand, yield was influenced by the rate of applied P in the fertilizer ratio. Thus, it seems that from a P nutrition standpoint with this turfgrass species, major attention should be given to the P applied as fertilizer and relatively less importance to the supply of the element supposedly already available in the soil (at least with the P extractant method used in this study).

Potassium Fertilization (1974, 1975, and 1977)

The rate of K applied and the number of applications had no significant influence on turfgrass quality, yield, or foliar N or P concentration. Plots receiving 1 pound of available K_20 per 1,000 square feet, applied only in the spring, were of lowest quality while those treated with a total of 27 pounds divided into three equal applications in the spring, summer, and fall had maximum scores (Table 19). Foliar K levels were also lowest and highest in these respective treatments. The effectiveness of using K in split applications at a high total rate is indicated in high rainfall areas where leaching occurs. Turf quality and foliar N levels were correlated ($r = 0.31^{**}$). (See Table 20.)

Yield and quality were not directly associated, but differences occurred in these plant responses, depending on the amount of rainfall during the year in which K_20 was applied (Figure 1, Table 19). The amount of the element applied and the number of applications per year influenced foliar K concentrations (Table 19). Extractable K ranged from 45 ppm in the medium with the lowest applied K_20 rate to 74 ppm in samples from plots receiving the highest application rate. Both foliar P and extractable P, however, were variable and unrelated to treatment in these samples (Table 19). Extractable P ranged erratically among K_20 treatments from 150 to 210 ppm.

Turfgrass quality was highest in 1974 and lowest in 1977. Yield and foliar N levels were highest in 1975 and lowest in 1977, while foliar K concentrations were higher in 1977 (no foliar analyses were available in 1974). (See Table 20.) This indicates that quality, as rated visually by panel members, was influenced more by N than by K nutrition, but also that both, at certain critical levels, could have had an effect on evaluation scores. Similar results with these elements and some micronutrients have been previously reported *(2)*. Other research *(13)* has indicated that panel ratings of turfgrass quality were a better measurement of K response than either foliar levels of the element or yield. In a related study, the time of

Table 19.—Mean effects of K on turfgrass quality, yield, and foliar nutrient concentrations

	1974, 1975, and 1977		1975 and 1977		
Treatment no.	Panel evaluation[1]	Yield[2]	Foliar N[3] (%)	Foliar P[3] (%)	Foliar K[3] (%)
1	6.1	33.0	4.49	0.63	1.15
2	6.3	35.3	4.49	0.50	1.33
3	6.2	35.4	4.42	0.50	1.51
4	6.2	34.3	4.46	0.49	1.34
5	6.3	33.2	4.47	0.49	1.43
6	6.3	35.8	4.47	0.49	1.62
7	6.3	32.8	4.52	0.50	1.36
8	6.3	34.7	4.51	0.49	1.51
9	6.4	34.1	4.44	0.47	1.65

[1] 1-9, 9 = best.

[2] Grams fresh weight/22 ft^2.

[3] Dry weight basis.

Table 20.—Influence of treatment and year on turfgrass quality, yield, and foliar N, P, and K concentrations

Treatment	Panel evaluation[1]			Yield[2]			% foliar N[3]		% foliar P[3]		% foliar K[3]	
no.	1974	1975	1977	1974	1975	1977	1975	1977	1975	1977	1975	1977
1	6.8	6.2	5.4	37.6	40.3	21.1	4.94	4.04	0.53	0.53	1.13	1.17
2	6.8	6.3	5.8	39.3	44.2	22.3	4.89	4.09	0.53	0.48	1.25	1.42
3	6.8	6.4	5.5	38.4	46.7	21.1	4.87	3.98	0.53	0.46	1.57	1.45
4	6.8	6.3	5.6	40.2	40.7	22.2	4.93	3.98	0.52	0.46	1.28	1.40
5	6.8	6.3	5.9	35.4	43.5	20.7	4.89	4.04	0.52	0.45	1.35	1.51
6	6.8	6.3	5.7	41.7	42.9	23.0	4.88	4.05	0.52	0.46	1.63	1.61
7	6.8	6.4	5.7	38.0	40.2	20.4	5.00	4.05	0.53	0.46	1.27	1.45
8	6.8	6.3	5.8	39.3	44.7	20.1	4.93	4.09	0.53	0.46	1.41	1.60
9	6.8	6.5	5.9	40.0	42.3	20.1	4.89	3.99	0.50	0.45	1.67	1.64

[1] 1-9, 9 = best.

[2] Grams fresh weight/22 ft^2.

[3] Seven foliar analyses, three in 1975 and four in 1977; dry weight basis.

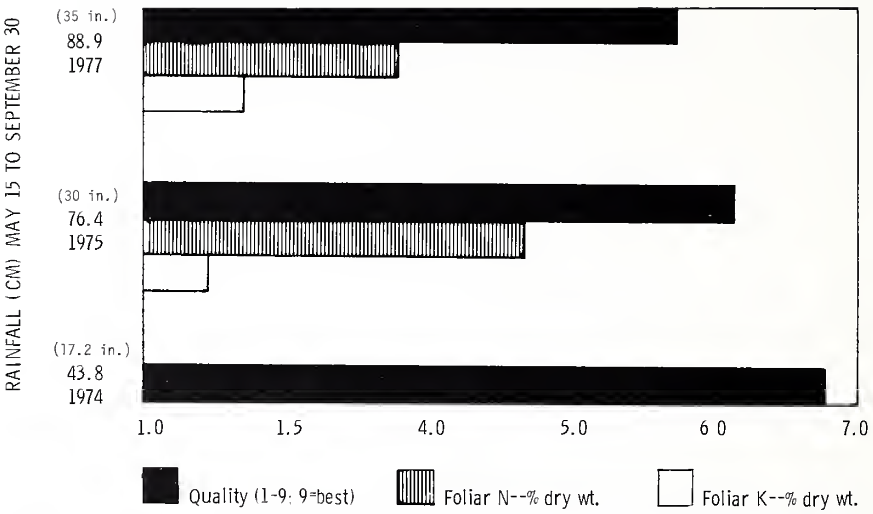

Figure 1.—Mean association between K treatments and rainfall, quality, and foliar N and K concentrations.

sampling for foliar analysis had more influence on the K content of clippings of *Poa pratensis* L. (Kentucky bluegrass) than the level of K fertilization *(17)*. Soil samples from these plots showed increasing amounts of K with increasing fertilizer rates and ranged in values considered by the author as medium to very high (no data given).

Yearly variations in turfgrass quality, foliar N and K, and extractable K reported here were probably caused by the leaching effect of rainfall on the applied nutrients. The medium in which the grass was grown consisted of 70 percent sand, 20 percent sphagnum peat, and 10 percent topsoil by volume, with an initial water infiltration rate of 5 inches per hour. The highest rainfall during the research period (35 inches) occurred in 1977, and the lowest (17 inches) was recorded in 1974. Turfgrass quality varied inversely with rainfall, as did the foliar N levels. Foliar K concentrations, however, did not exhibit the same pattern as N, reaching the highest amounts in 1977 (Figure 1). Other research with 'Tifgreen' bermudagrass here, in the same environment and growing medium, has also indicated that soil and foliar N levels were lowered by leaching and/or high temperature and organic matter influences. Foliar and soil K were also reduced during the season by high rainfall *(2)*.

The effect of the number of applications and amount of K_2O applied per year on foliar K levels, and the correlation between turf quality and foliar N, show interrelationships when critical levels of these nutrients are reached. More frequent applications of K_2O and the use of a more slowly soluble N source may offer a partial solution. Slowly soluble forms of N and K combined (other than in Milorganite sewage sludge) are generally not used on golf greens due to the low mowing height, which results in damage to coated pellets, and the high cost of such fertilizers. Three or more K_2O applications per season may be necessary, along with the proper source and rate of N *(2)* and a good supply of P, for optimum quality of 'Tifgreen' bermudagrass grown on USGA golf greens in Louisiana.

Summary

Research was conducted from 1974 to 1981 to determine some of the nitrogen, phosphorus, and potassium fertility requirements of 'Tifgreen' bermudagrass planted on golf greens constructed according to U.S. Golf Association specifications in a warm, humid environment.

Nitrogen sources used were ammonium nitrate, ureaformaldehyde (UF), isobutylidene diurea (IBDU), sulfur-coated urea (SCU), and activated sewage sludges (Hi-Organic and Milorganite). Milorganite, at most rates and application frequencies, was superior to all other fertilizers in producing high-quality golf green turfgrass, as evaluated by visual ratings of a panel of faculty members and golf superintendents. Six pounds of Milorganite nitrogen per 1,000 square feet per growing season (April to October), applied at the rate of 2 pounds of nitrogen every 2 months, provided a higher quality putting surface in 1979 and 1980 than all other sources and rates used except those of 12 and 18 pounds of Milorganite nitrogen, which were uneconomical to apply. One pound per month of Milorganite nitrogen, or other sources used in this research (6 pounds of nitrogen per season), resulted in the lowest quality turfgrass. Some turfgrass injury resulted when IBDU was applied at rates of 2 or more pounds of nitrogen per 1,000 square feet, regardless of application frequency.

Phosphorus research showed that this element (from superphosphate) did not influence turfgrass quality directly, but may have had an indirect effect since phosphorus was related to yield, and yield and quality were interrelated. However, soil test analyses indicated yield was influenced only by the applied phosphorus and not by the amount of phosphorus present in the soil. The amount of the element present in grass clippings, based on foliar analyses, was related to turfgrass yield in this study, and the amount of phosphorus applied did influence the concentrations of that element present in the grass foliage. It appeared, in this research, that major attention should be given to the phosphorus applied as fertilizer and relatively less importance to the supply of the element supposedly already available in the soil.

Neither the rate of applied potassium (from potassium chloride) nor the number of applications had a significant influence on turfgrass quality or yield. However, the amount of the element applied and the number of applications did influence the amount of potassium and nitrogen present in

the foliage and the potassium in the growing medium, which were related to quality. Thus, the effectiveness of using potassium in split applications at a high total rate is indicated for high rainfall areas such as Louisiana, where leaching occurs. Three or more potassium applications per season may be necessary, along with the proper source and rate of nitrogen and a good supply of phosphorus, for optimum quality of 'Tifgreen' bermudagrass on USGA golf greens in Louisiana.

It should be kept in mind that all data presented here were obtained with 'Tifgreen' bermudagrass grown in the medium, at nutritional levels, and in the environment previously described. Results could vary with different species, under different conditions. Additional research will be necessary to determine if these data are valid in other situations of climate, species, and media.

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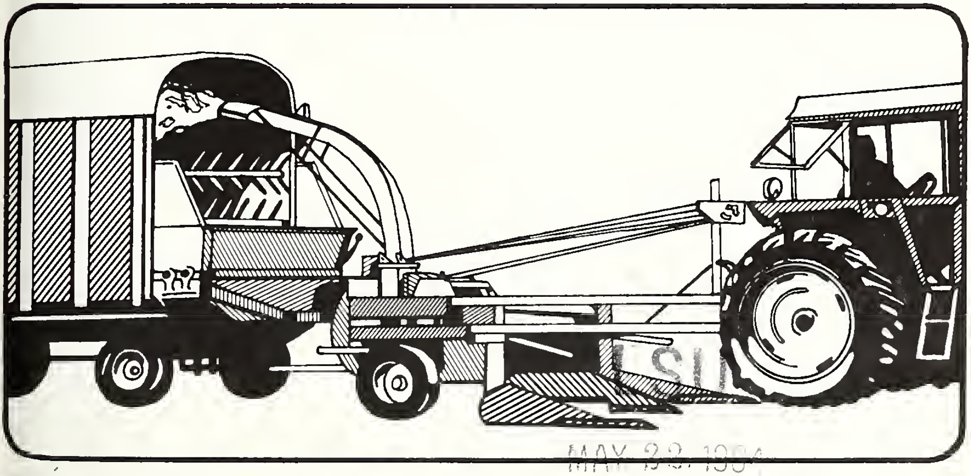

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Nutritional and Agronomic Comparisons of Cowpeas, Millet, and Sorghum

CHARLES R. MONTGOMERY, MARVIN ALLEN, AND LEE MASON[1]

Introduction and Objectives

Many dairymen in southeast Louisiana are utilizing summer-growing annual grasses to provide grazing or greenchop for lactating animals. In view of the high cost of commercial fertilizers during recent years, and for other reasons, some area farmers have been planting and grazing cowpeas to minimize fertilizer expenditures as compared with growing summer annual grasses. Cowpeas require less nitrogen fertilization than summer annual grasses, millet, sorghum, and sorghum-sudan, which are commonly used to provide grazing and greenchop for dairy herds. Millet produces high yields, but it is generally difficult to manage as a grazing crop due to its rapid growth and short vegetative cycle. Most sorghum plantings are not grazed but are greenchopped or harvested and stored as silage, which requires more equipment and investment. Because of farmer interest, there is a definite need for information on forage production and quality potential of cowpea varieties and how they compare with millet and sorghum. An experiment was conducted at the Southeast Louisiana Dairy and Pasture Experiment Station with cowpeas, millet, and sorghum to pursue the following objectives: (1) to determine the forage production potential of existing varieties of cowpeas, (2) to evaluate the quality of forage produced by cowpeas, and (3) to evaluate forage and nutrient production of cowpeas as compared with millet and sorghum.

Review of Literature

Cowpeas are widely adapted in the South and are grown on a limited scale for soil improvement and hay and forage production *(5)*[2]. In the Upper South seed yields are good, but in the Lower South plants tend to produce vegetative growth rather than seed. Cowpeas generally can be grown without cultivation due to their quick germination and rapid seedling growth.

An extensive search of the literature revealed no recent publications on the use of cowpeas for forage production.

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[2] Italic numbers in parentheses refer to Literature Cited, page 12.

Cowpeas were planted on a field-scale basis for summer grazing in the summer of 1975 at the Southeast Louisiana Dairy and Pasture Experiment Station. The plantings were made for observational purposes and were not designed to furnish experimental data.

A 25-acre field was planted to Iron Clay cowpeas without applied fertilizer on July 8, 1975. The peas were 12 to 14 inches high on July 24, and grazing was initiated with 6-month-old dairy heifers on that date. The field provided a total of 40 days of grazing and averaged 3.75 animals (6-month-old dairy heifers) per acre.

In another observation at the Southeast Station, Iron Clay cowpeas were planted on July 7, 1975 and received 90-72-72 pounds per acre of N, P_2O_5, and K_2O, respectively, before planting. Grazing was initiated on August 6, when the peas were approximately 24 inches high, with a stocking rate of 2.4 mature, 1,200-pound Holstein cows per acre. The cows grazed 4 to 5 hours per day for 6 days. To more efficiently utilize the forage, the stocking rate was increased to 5.6 animals per acre in the next 15 days. Forage from this planting supplied grazing for 99 cow-days per acre, based on a 4- to 5-hour grazing period per day.

Further observations made during the grazing periods revealed that when animals were given a choice they would graze crabgrass or millet before consuming the peas. It also was noted that excessive trampling occurred with a stocking rate of five cows per acre.

Millet varieties have been evaluated for forage production at the Southeast Louisiana Dairy and Pasture Experiment Station *(3)*. Millet generally can be harvested 30 days after planting and at 3-week intervals thereafter, for a total of four harvests. Total dry matter yields of the millet varieties ranged from 7,742 pounds per acre to 8,886 pounds per acre.

Louisiana researchers have shown that millet varieties generally are superior to the sorghum-sudan hybrids on well-drained, light soils, while the sorghum-sudan hybrids are superior to millet on heavier soils *(6)*. Millet is recommended for grazing and hay production but should not be planted before April 15. Fertilization requirements for millet in southeast Louisiana include 60 to 90 pounds of nitrogen and 60 to 70 pounds each of P_2O_5 and K_2O per acre before planting. An additional 50 pounds per acre of nitrogen as a top dressing may be utilized.

Forage sorghum dry yields at the Southeast Louisiana Dairy and Pasture Experiment Station have ranged from 4,200 to 10,800 pounds per acre *(1)*. Fertilization requirements for forage sorghum in southeast Louisiana are comparable to those of millet. Forage sorghum is superior to millet for greenchopping, especially as the plants mature. The longevity of sorghum palatibility makes the crop more manageable than millet in a dairy program.

Experimental Procedure

This study was conducted in two phases, (1) a small-plot agronomic and laboratory screening process to evaluate available varieties of cowpeas, and (2) comparison of a superior variety of cowpeas with millet and sorghum on a field-scale basis.

The first phase included 12 varieties of cowpeas grown during the summers of 1976 and 1977. The forages were grown in small plots, 6 x 25 feet, and replicated four times using a randomized design. Each plot consisted of two rows on 36-inch centers. Seeding rate was adjusted among cowpea varieties, because of differences in seed size, to have 10 to 12 plants per linear foot of row. The plantings were made on a Providence silt loam soil. Fertilization of the cowpeas included 48 pounds per acre each of N, P_2O_5, and K_2O. The cowpea forage was harvested while in the vegetative stage (pre-bloom) to a stubble height of approximately 6 inches. Harvesting was accomplished with a flail-type forage harvester. The entire plot was harvested to measure yield, and a representative sample was taken, dried for dry matter determination, and then ground for laboratory analyses. Regrowth from all plots was harvested as often and as long as productivity persisted.

Cell wall constituents (CWC), acid detergent fiber (ADF), hemicellulose, cellulose, acid-insoluble lignin (AIL), and in vitro digestible dry matter (IVDDM) were determined by the Van Soest procedure *(4, 8)*. The IVDDM procedure was modified by the addition of glucose and urea to the buffer solution *(7)*. Crude protein (CP) content was determined by the Kjeldahl method, as outlined in A.O.A.C. *(2)*.

The second phase of this study involved the comparison of the most promising cowpea variety (Big Boy), a millet (Millex 23), and a sorghum (NK 300), each planted and managed on a field-scale basis in 1978, 1979, 1980. Each variety was planted in 8-inch drills on adjacent ¼-acre blocks on a prepared seedbed. Treflan (4 pounds per gallon) was applied at the rate of 0.5 pound active material per acre on the site planted to cowpeas. Aatrex 4L was applied at the rate of 2 quarts per acre on the area planted to sorghum. Seeding rates and fertilization rates (N-P_2O_5-K_2O), respectively, on a per acre basis were: 2 bushels and 20-60-120 for cowpeas, 30 pounds and 80-40-80 for millet, and 40 pounds and 80-40-80 for sorghum.

The millet and sorghum forages were harvested in the vegetative stage, when plants reached heights of 24 to 30 inches, and 36 to 48 inches, respectively; and 8-inch stubble remained after harvest. The cowpea variety was harvested to a 6-inch stubble height at the prebloom stage. Yield data were obtained by harvesting five random strips, 6 x 10 feet, from each of the plots. The plots were harvested as greenchop with a flail-type harvester and dried in a forced-draft drier at 130° F.

Each dried forage was chopped to approximately ½-inch lengths with a hammer mill and fed to sheep to determine digestible dry matter (DDM). The digestion trial involved four sheep on each forage, which served as replicates, with a 9-day preliminary period, followed by a 5-day total-fecal-collection period. The sheep were maintained in conventional digestion crates that permitted individual feeding twice daily, weigh-backs once daily, and total fecal collection.

The chopped forages and fecal materials were sampled during each digestion trial, dried, and ground in a Wiley Mill to 1-millimeter fineness for laboratory analyses. Laboratory analyses were the same as described previously in phase one. Analyses of the forages and fecal materials were used to calculate component digestibilities.

Results and Discussion

1. *Cowpea Variety Comparisons*

Dry forage yield per acre. The cowpea varieties were initially harvested at 6 and 8 weeks after planting, which was the bloom stage, in 1976 and 1977, respectively. Two harvests were made each year, with approximately 75 percent of the season-total yield contributed by the first harvest in 1976 and approximately 45 percent obtained at first harvest in 1977. Forage yields ranged from 1,261 to 3,513 pounds per acre in 1976 and from 2,349 to 2,895 pounds per acre in 1977 (Table 1). Significant ($P < .05$) differences were observed in 2-year mean dry-forage yields, with a range from 1,891 to 3,101 pounds per acre. The 2-year mean dry forage yield of one variety, Big Boy, was numerically higher than all others and significantly ($P < .05$)

Table 1.—Yield performance and dry matter content of 12 cowpea varieties on Providence silt loam, 1976-77

	DM yield, lbs/a			Dry matter, %		
Variety	1976	1977	2-yr mean	1976	1977	2-yr mean
Big Boy	3,446	2,755	3,101a[1]	15.2	12.7	14.0[2]
Blue Goose	3,513	2,488	3,001ab	15.9	13.4	14.7
Brown Crowder	2,924	2,874	2,899ab	16.2	12.0	14.1
Miss. Purple	2,894	2,895	2,895ab	17.0	12.8	14.9
Iron Clay	2,802	2,645	2,724b	15.0	12.3	13.7
Miss. Silver	2,791	2,642	2,717b	16.6	12.7	14.7
Dixie Lee	2,864	2,555	2,710b	15.6	13.2	14.4
Black Crowder	2,715	2,684	2,700b	15.4	12.6	14.0
Calhoun Purple Hull	2,695	2,529	2,612b	15.7	11.7	13.7
Bunch Purple Hull	1,734	2,747	2,241c	16.9	13.5	15.2
Magnolia Blackeye	1,833	2,349	2,091c	16.2	13.5	14.9
La. Green	1,261	2,520	1,891c	15.7	12.5	14.1

[1] Means followed by the same letter are not significantly different at the .05 probability level.

[2] Nonsignificant at the .05 probability level.

higher than the yields of eight other varieties. Three varieties, Bunch Purple Hull, Magnolia Blackeye, and Louisiana Green, were significantly (P <.05) lower than all other varieties in 2-year forage yield.

Forage dry matter percentages. Forage dry matter percentages ranged from 11.7 to 17.0 during the 2-year period (Table 1). No significant differences were observed in 2-year mean dry-matter percentages among varieties, with only a 1.5 percentage unit range.

Structural carbohydrates. Cell wall constituents (CWC) includes the total fibrous fraction of the forage. Included are acid detergent fiber (ADF) and hemicellulose. The ADF is further subdivided into cellulose and acid insoluble lignin (AIL). The fibrous portion of the plant is the material acted on by microflora in the rumen. No variety was consistently high or low for all structural carbohydrates. Ranges in percentages of structural carbohydrates among varieties were as follows: CWC 32.5 to 35.2, ADF 27.2 to 28.8, hemicellulose 4.5 to 6.5, cellulose 18.1 to 20.5, and AIL 4.90 to 5.74. These differences were numerically small and of no practical significance. However, structural carbohydrate percentages in those ranges indicate that all varieties were high in quality.

Crude protein. Crude protein (CP) percentages of the cowpeas, a legume crop, were all high and exhibited very small varietal differences (Table 2). There were, however, significant (P <.05) differences in CP percentages among the 2-year means. There was no significant difference in the highest five CP means, with a range from 24.4 to 25.5 percent. Seven of the 12 varieties exhibited CP values ranging from 23.1 to 24.2 percent and were

Table 2.—Chemical composition and in vitro digestible dry matter of 12 cowpea varieties, 2-year mean, 1976-77

Variety	CWC[1]	ADF[1]	HC[1]	Cell.[1]	AIL[1]	CP[1]	IVDDM[1]
				Percent			
Magnolia Blackeye	34.1	27.6	6.4	20.2	4.90	24.2bc[2]	71.1[3]
Miss. Purple	33.1	28.8	4.5	20.3	5.52	23.3bc	70.8
Brown Crowder	33.6	27.8	5.8	19.7	4.96	23.5bc	70.7
Big Boy	32.5	28.0	4.6	19.8	5.02	23.6bc	70.6
Iron Clay	34.0	28.3	5.5	20.3	5.31	23.7bc	70.5
Dixie Lee	34.0	28.5	5.5	20.2	5.18	23.1c	70.3
Calhoun Purple Hull	35.2	28.7	6.5	20.5	5.74	24.6ab	70.3
Bunch Purple Hull	32.8	27.2	5.7	18.1	5.28	24.4abc	70.3
La. Green	34.1	28.0	6.1	19.7	5.32	25.5a	70.3
Black Crowder	33.2	28.1	5.1	19.7	5.55	24.6ab	70.2
Miss. Silver	32.7	28.0	4.7	19.5	5.59	24.5abc	69.8
Blue Goose	33.4	28.2	5.3	20.3	4.97	23.5bc	69.2

[1] Cell wall constituents, acid detergent fiber, hemicellulose, cellulose, acid-insoluble lignin, crude protein, and in vitro digestible dry matter, respectively.

[2] Values followed by the same letter are not significantly different at the .05 probability level.

[3] Nonsignificant at the .05 probability level.

not significantly different. Mean CP values ranged from 23.1 to 25.5 percent. There was no consistent change in CP percentages between the first and second harvests.

In vitro digestible dry matter. In vitro digestible dry matter (IVDDM) is generally regarded as a relative measure of the nutritional value of a forage. All tested varieties exhibited high mean values for IVDDM, ranging from 69.2 percent for Blue Goose to 71.1 percent for Magnolia Blackeye (Table 2). These observed differences were not statistically significant. IVDDM value of the forage harvested at the second harvest was consistently 1 to 2 percentage units higher than that of the respective first harvest. This increase may be attributed to the younger forage that was harvested as regrowth.

II. *Millet, Sorghum, and Cowpea Comparisons*

Dry forage yield per acre. The millet (Millex 23), sorghum (Northrup King 300), and cowpeas (Big Boy) were planted in late May or early June in each of 3 years (1978-80). The first harvest of Millex 23 and NK 300 was made an average of 37 days after planting, while Big Boy averaged 44 days from planting to first harvest. Millex 23 and NK 300 were harvested an average of three and two times per year, respectively, while Big Boy averaged 1.6 harvests per year. Season-total and 3-year mean, dry-forage yields, in pounds per acre, and dry matter percentages of the forages are shown in Table 3. The average dry forage yields per acre were significantly ($P < .05$) lower for NK 300 (4,480 pounds) than Millex 23 (6,033 pounds),

Table 3.—Yield and forage component comparisons of millet, sorghum, and cowpea forages on Providence silt loam, 1978-80

Cultivar	1978	1979	1980	Mean
		Dry matter yield, lbs/a		
Millex 23	7,210	5,258	5,404	6,033a[1]
NK 300	5,453	4,242	3,489	4,480b
Big Boy	2,021	3,476	3,382	2,959c
		Percent dry matter		
Millex 23	17.3	12.3	13.3	14.3a
NK 300	12.5	15.5	12.8	13.6b
Big Boy	10.8	11.5	9.8	10.7c
		Digestible dry matter, lbs/a[2]		
Millex 23	4,835	3,248	3,722	3,929a
NK 300	3,659	2,732	2,400	2,893b
Big Boy	1,429	1,997	2,389	1,886c
		Crude protein, lbs/a		
Millex 23	1,365	821	978	1,069a
NK 300	844	588	652	729ab
Big Boy	455	751	760	655b

[1] Means followed by the same letter are not significantly different at the .05 probability level.

[2] Based on DDM values.

but significantly ($P < .05$) higher than Big Boy (2,959 pounds).

The 3-year mean DM percentage (10.7) for the Big Boy was significantly ($P < .05$) lower than that of Millex 23 and NK 300. Millex 23 exhibited the highest forage DM content (14.3 percent), which was significantly ($P < .05$) higher than that of NK 300 or Big Boy.

Nutrient production per acre. DDM production per acre followed the same trend established by dry forage yield per acre since there was no significant difference in forage digestibility among the three crops (Table 3). Millex 23 produced the highest 3-year mean DDM per acre (3,929 pounds), which was significantly ($P < .05$) higher than NK 300, with 2,893 pounds per acre, and Big Boy, with 1,863 pounds per acre. The DDM production per acre of NK 300 was significantly ($P < .05$) higher than that of Big Boy. This pattern of DDM production was consistent for all 3 years.

The 3-year mean production of CP per acre was numerically highest with Millex 23 at 1,069 pounds per acre (Table 3). However, there was no significant difference in the 3-year mean CP production per acre between Millex 23 and NK 300. Big Boy, with a 3-year mean CP production of 655 pounds per acre, was significantly ($P < .05$) less productive than Millex 23. In 1979 and 1980, Big Boy produced more CP per acre than NK 300.

Chemical composition. Structural carbohydrate and crude protein percentages for each year and 3-year means are shown in Table 4. Lower structural carbohydrate percentages indicate higher quality, since the struc-

Table 4.—Chemical composition and digestibility of millet, sorghum, and cowpea forages, 1978-80

Cultivar	CWC[1]	ADF[1]	HC[1]	Cell.[1]	AIL[1]	CP[1]	IVDDM[1]	DDM[1]
	Percent							
				1978				
Millex 23	60.4	29.4	31.0	25.4	3.38	19.3	66.8	63.5
NK 300	64.8	33.8	31.0	28.8	4.10	15.5	66.5	55.4
Big Boy	47.3	28.1	19.2	22.5	5.25	22.5	70.7	62.9
				1979				
Millex 23	62.7	34.3	28.5	29.2	3.75	16.6	65.3	62.6
NK 300	65.4	37.1	28.4	31.4	4.63	14.1	65.4	64.4
Big Boy	45.0	33.0	12.1	24.0	5.95	22.2	64.7	58.6
				1980				
Millex 23	60.1	31.8	27.1	27.8	2.51	17.8	70.5	69.6
NK 300	59.4	30.8	28.6	27.1	2.53	18.6	72.6	68.8
Big Boy	45.5	33.3	12.2	27.1	4.95	22.3	71.1	70.7
				Mean				
Millex 23	61.1a[2]	31.8a	28.9a	27.5a	3.21a	17.9b	67.5a	64.8a
NK 300	63.2a	33.9a	29.4a	29.1a	3.75a	16.1b	68.2a	63.1a
Big Boy	45.9b	31.5a	14.5a	24.5a	5.38b	22.3a	68.8a	64.1a

[1] Cell wall constituents, acid-detergent fiber, hemicellulose, cellulose, acid-insoluble lignin, crude protein, in vitro digestible dry matter by Van Soest procedure, digestible dry matter with sheep, respectively.

[2] Means followed by the same letter are not significantly different at the .05 probability level.

tural carbohydrates must be acted upon by the microorganism of the rumen to provide available energy to the animal. There was no significant difference among any of the structural carbohydrate percentages of Millex 23 and NK 300 forages. Three-year mean CWC and hemicellulose percentages of the Big Boy were significantly ($P < .05$) lower than those of Millex 23 and NK 300. There was no significant difference in the 3-year mean ADF and cellulose percentages among the three crops. Big Boy exhibited a significantly ($P < .05$) higher 3-year mean AIL percentage than Millex 23 or NK 300.

Crude protein. The 3-year mean CP percentage of Big Boy forage (22.3) was significantly ($P < .05$) higher than that of Millex 23 or NK 300 with 17.9 and 16.1, respectively (Table 4). There was no significant difference in CP percentages of Millex 23 and NK 300. CP of the individual harvests of Big Boy ranged from 20.0 to 24.6 percent, while Millex 23 and NK 300 had CP percentages of 12.9 to 20.5, and 11.7 to 19.0, respectively.

In vitro and in vivo digestibility. Neither in vitro nor in vivo digestibility values were significantly different among crops as shown in Table 4. All three crops were high in quality, with 3-year DDM percentages ranging from 63.1 for NK 300 to 64.8 for Millex 23 forage. There was a tendency for digestibility value to decrease as the season advanced.

Component digestibility. With the exception of cellulose, there was no significant difference in 3-year mean digestibility of carbohydrates of Millex 23 and NK 300 forages (Table 5). Big Boy exhibited significantly (P

Table 5.—Component digestibility[1] of millet, sorghum, and cowpea forages, 1978-80

Cultivar	CWC[2]	ADF[2]	HC[2]	Cell.[2]	CP[2]
			Percent		
			1978		
Millex 23	66.5	57.6	75.6	67.9	67.0
NK 300	67.1	59.8	73.9	72.9	66.3
Big Boy	63.4	53.9	77.4	68.8	69.4
			1979		
Millex 23	68.3	61.3	73.0	70.2	61.8
NK 300	67.5	62.4	73.9	76.1	67.0
Big Boy	55.7	48.3	75.5	63.0	67.4
			1980		
Millex 23	73.6	66.6	82.1	78.6	69.8
NK 300	72.6	62.5	81.3	78.7	73.1
Big Boy	76.3	72.0	80.2	84.1	72.9
			Mean		
Millex 23	69.5a[3]	61.8a	76.9a	72.2b	66.2b
NK 300	69.3a	61.9a	76.7a	76.0a	68.9ab
Big Boy	65.0b	58.1b	77.7a	72.0b	69.9a

[1] Based on forage and fecal samples.

[2] Cell wall constituents, acid-detergent fiber, hemicellulose, cellulose, crude protein, respectively.

[3] Means followed by the same letter are not significantly different at the .05 probability level.

$<.05$) lower CWC and ADF digestion values than Millex 23 and NK 300. There was no significant difference in 3-year mean hemicellulose digestibility among the three crops. Cellulose digestibility of NK 300 was significantly ($P <.05$) higher than those of Millex 23 or Big Boy, which were not significantly different. Crude protein digestibility values of NK 300 and Big Boy were not significantly different, but Big Boy was significantly ($P <.05$) higher than that of Millex 23. There was no significant difference in 3-year mean CP digestibility of Millex 23 and NK 300. All component digestibilities were high, indicating that all three crops were high in quality.

Summary and Conclusions

Twelve cowpea varieties were grown for 2 years in replicated small plots and evaluated for forage yield, chemical composition, and digestibility. Four of these varieties produced significantly more season-total dry forage than eight other varieties. Two harvests were made each year, with approximately 1½ tons of dry forage produced by each of the top four varieties. There were no significant differences in dry matter percentages and IVDDM of the 12 varieties.

One cowpea variety, Big Boy, was chosen to be compared with a millet, Millex 23, and a sorghum, NK 300, on a field-scale basis for 3 years. Forage was available for three harvests per year with the Millex 23, two with NK 300, and 1.6 with Big Boy. Season-total forage yield of Millex 23 was consistently higher than that of NK 300 and Big Boy. Big Boy consistently produced less dry forage per acre than NK 300 and Millex 23. Forage dry matter content of Big Boy was significantly ($P <.05$) lower than that of Millex 23 or NK 300.

There was no significant difference in animal DDM and in vitro digestible dry matter among the three crops.

Crude protein content of Big Boy forage was significantly ($P <.05$) higher than that of Millex 23 and NK 300. There was no significant difference in CP percentage of Millex 23 and NK 300.

DDM production per acre followed the same trend noted in dry yield, since there was no significant difference in digestibility of the crops. There was no significant difference in per acre CP production of Millex 23 and NK 300. Big Boy produced significantly less CP per acre than Millex 23.

There was no significant difference in structural carbohydrate percentages between Millex 23 and NK 300. CWC and hemicellulose percentages of Big Boy were significantly ($P <.05$) lower than those of Millex 23 or NK 300.

With the exception of cellulose, there was no significant difference in digestibility of structural carbohydrates of Millex 23 and NK 300 forages.

Big Boy exhibited significantly (P <.05) lower CWC and ADF digestion values than Millex 23 or NK 300.

Crude protein digestibility of Big Boy forage was significantly (P <.05) lower than that of Millex 23, but it was not significantly different from NK 300.

These data reveal that Millex 23 and NK 300 yields were superior to that of Big Boy. While all three crops were high in quality, the nutrient production per acre of the cowpea (Big Boy) was inferior to millet (Millex 23) and sorghum (NK 300). The use of cowpeas in a forage program with the aim of minimizing nutrient production cost per acre while maintaining economical forage yield level would be questionable.

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A Computer Model for Trailer Optimization in a Cotton Harvesting System

George R. Baskin　　**Fred E. Sistler**

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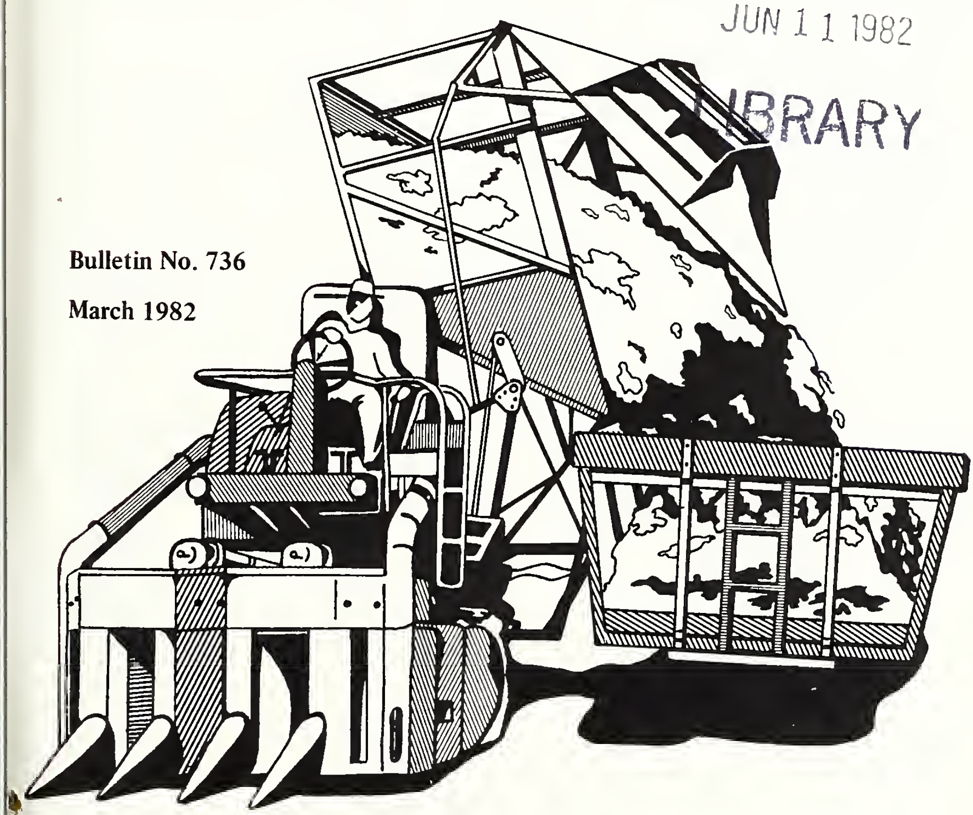

Bulletin No. 736

March 1982

LOUISIANA STATE UNIVERSITY
AND AGRICULTURAL AND MECHANICAL COLLEGE
Center for Agricultural Sciences
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A Computer Model for Trailer Optimization in a Cotton Harvesting System

GEORGE R. BASKIN AND FRED E. SISTLER[1]

Inflation has hit the cotton farmer. The prices of products he must buy to produce a crop have risen drastically, but the price he receives for his cotton has not kept pace with his production costs *(3)*.[2]

The cotton farmer must produce his crop more efficiently to remain in business. The computer can be a valuable tool in farm management; computer models can pinpoint where the farmer's dollars should be invested to reap the greatest returns.

Harvesting is one of the most important steps in cotton production because the crop must be harvested before weather can lower its quality. The cotton farmer must consider not only the fixed and operating costs of a harvesting system but also the ability of the system to harvest the crop within the allowable harvest season.

A computer program based on information from farm records has been developed to aid in the design of the cotton harvesting system. The performance rates and fixed and operating costs of five components are included—the cotton harvester, the trailer transport vehicle, cotton trailers, the gin, and labor.

The computer model divides cotton harvesting into two segments. The picking subroutine assumes a cotton harvester and the cotton trailers in the field. When the basket is full, the harvester dumps the cotton into a trailer if one is available; if not, it waits for an empty trailer to return to the field. Each trailer is filled to capacity.

The transport subroutine simulates all the cotton trailers in the field or at the gin and a truck to pull the trailers. The truck takes the full trailers to the gin, returns the empts trailers to the field, and remains in the field when no trailers are waiting for transport. The truck brings all trailers emptied at the gin, returns the empty trailers to the field, and remains in the field when no

The model has a weather component based on data collected concerning the number of days suitable for fieldwork *(1)*. Depending on the date on which the farmer decides to begin his harvest, the model accounts for a given number of days on which the system will be idled by weather.

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[2] Italic numbers in parentheses refer to Literature Cited, page 15.

Date in this publication are reported in English units of measure. For conversion to metric equivalents, 1 acre = .4047 hectare, and 1 mile = 1.6093 kilometers.

Many of the concepts used in developing this model have been adapted from a report on a sugarcane transport system designed by Cochran and Whitney *(2)*. The actual components in the cotton harvesting system have been based on the authors' experience. The data used to evaluate the program were from reports on cotton production costs and agricultural statistics for Louisiana *(3, 4, 5)*.

Assumptions and Limitations of the Model

The model was developed for a one-harvester, one-truck system. The number of trailers was varied from one to 15. For a system with more than one picker, average values for picking rate, fixed costs, etc., could be used in the model to give a reasonable estimate for a multiple-picker system. At present there is no convenient way to increase the number of trucks used to transport trailers to and from the gin in the model.

The gin time for trailer turnaround was assumed to be constant throughout the harvesting season, but this is not completely accurate because turnaround time varies widely. Gin turnaround times of 48 and 96 hours were used in the model.

An approximate count was used for days not worked due to unavailability of trailers. If more than 75 percent of the working day was worked, it was considered a whole working day; if 50 to 75 percent of the day was worked, it was half a working day. If less than 50 percent of the working day was used, it was not included as a working day.

The length of a full working day was assumed to be constant. The work day began with the picker, truck, and available empty trailers already in the field. Servicing and maintenance of equipment and travel time to and from the field were not included in the work day. Operating costs, which included all maintenance and service costs, and labor costs were considered separately.

The harvest season was limited to the period from September 20 through December 31 (103 days). Estimated harvesting delays caused by bad weather were based on the study by Bolton *et al. (1)*. The computer model assumed the weather caused either a full day's delay or no delay at all. Each day's weather was considered to be unaffected by the weather of the preceding day. The economic loss related to deterioration in quality and quantity of mature cotton subjected to bad weather was not considered because that information was unavailable. If this economic loss had been included, it would have shown extra trailers to be of greater economic value to the farmer when harvesting was delayed by a lack of empty trailers.

The availability of rental trailers from the gin was not considered. However, the program did consider an average fixed and operating cost for the trailers. Therefore, for a situation with both rented and farmer-owned trailers, the average costs could be applied in the model if the number of trailers remained constant throughout the harvesting season. There was no way for the program to consider a system in which the number of trailers varied during the harvest season.

Results

The computer program was run with various yield levels, farm sizes, numbers of pickers, ginning times, and soil types. The farm sizes used were 200, 400, 600, and 800 acres. For the 400 acre farm, the yield was varied from .75 to 1.5 bales per acre. The one- and two-picker systems were tested on the 600- and 800-acre farms. The effect of inefficient picker operation was also tested and examined. When one factor was varied, all other variables were held constant (Table 1).

The effect of trailer capacity was modeled using four-, seven-, and ten-bale trailers (Figure 1). It usually required fewer large trailers than small trailers to achieve the minimum harvest cost. The use of larger trailers showed a slight trend toward a lower overall harvesting cost. In every case, the least harvest cost and minimum harvest season length occurred with the same number of trailers. The harvest season length stabilized after the minimum point (Figure 2). The picker was 100 percent utilized at this point and never stopped to wait for a trailer to return from the gin. The addition of trailers beyond this optimal point did not drastically increase cost. The grower could invest in one or two additional trailers at very little extra cost as insurance against a rainy year or gin breakdown.

When picker rates of 1 and 1.75 acres per hour were compared (Figures 3 and 4), the higher rate required more trailers and had a lower per-bale harvesting cost. The slower picker rate raised harvest costs by $20 per bale, used the maximum harvest season of 103 days, and left 50 bales of cotton in the field on a 400-acre farm.

Table 1.—Sample inputs for the cotton harvesting model

Picker data
- Operator's wages = $3.50/hour
- Fixed cost = $3,940/year
- Operating cost = $24.85/machine hour
- Picking rate = 1.75 acres/hour
- Basket capacity = 2 bales

Truck data
- Driver's wages = $3.50/hour
- Fixed cost = $.06/mile
- Operating cost = $.11/mile

Trailer data
- Fixed cost = $190.33/year
- Operating cost = $.03/mile
- Capacity = 10 bales
- Average gin turnaround time = 48 hours

General input data
- Average distance to gin = 8.5 miles
- Average working day length = 10 hours
- Total cotton acreage = 400 acres
- Average yield = 1 bale/acre

The effect of ginning time was evaluated for 48- and 96-hour turnaround times (Figures 5 and 6). The longer ginning time increased the number of seven-bale trailers needed to minimize harvesting cost from seven to 10.

Farm size had little influence on the optimal number of trailers. Farms

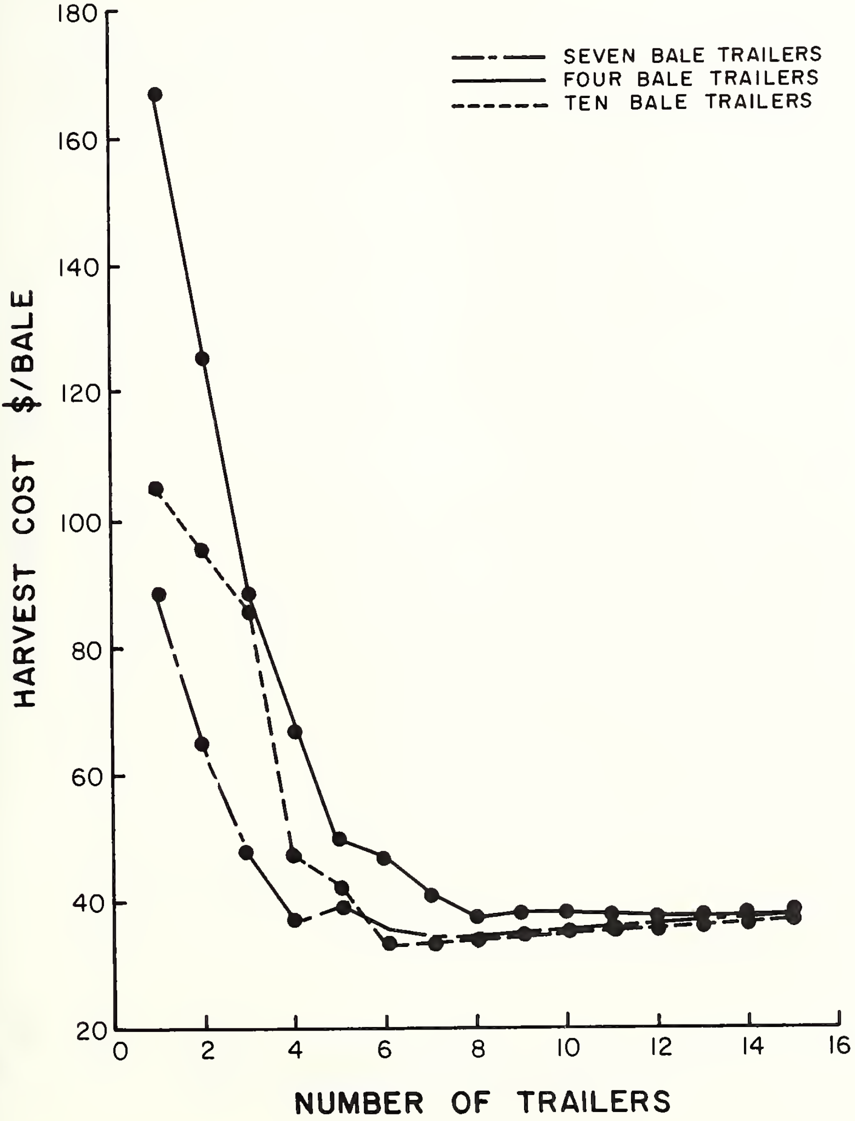

Figure 1.—Effect of trailer size on harvest cost. (400-acre farm, 1 picker with 1.75 acre/hr rate, 48-hr gin time.)

from 200 to 600 acres all required six 10-bale trailers if one picker was used. Farms of 600 acres and larger with two pickers needed eight 10-bale trailers.

Farm size had little effect on the system performance (Figures 7 and 8). However, the results for the 600-acre farm with one- and two-picker

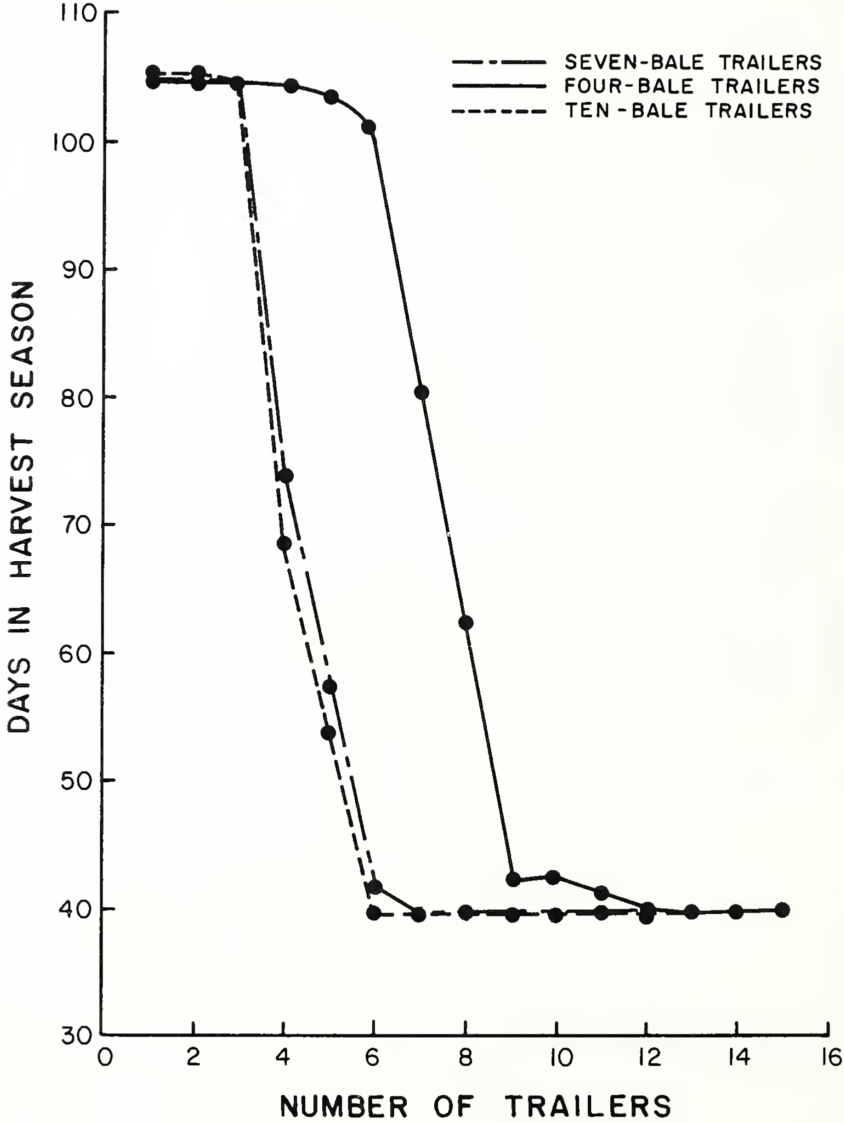

Figure 2.—Effect of trailer size on harvest season length. (400-acre farm, 1 picker with 1.75 acre/hr rate, 48-hr gin time.)

systems showed that both the lease cost and minimum harvest season must be considered. While the one-picker system is less expensive, the associated 85-day harvest season is unacceptable. For best performance, the two-picker systems generally required more trailers than did the one-picker systems.

Sensitivity to crop yield was examined on the 400-acre farm with yields

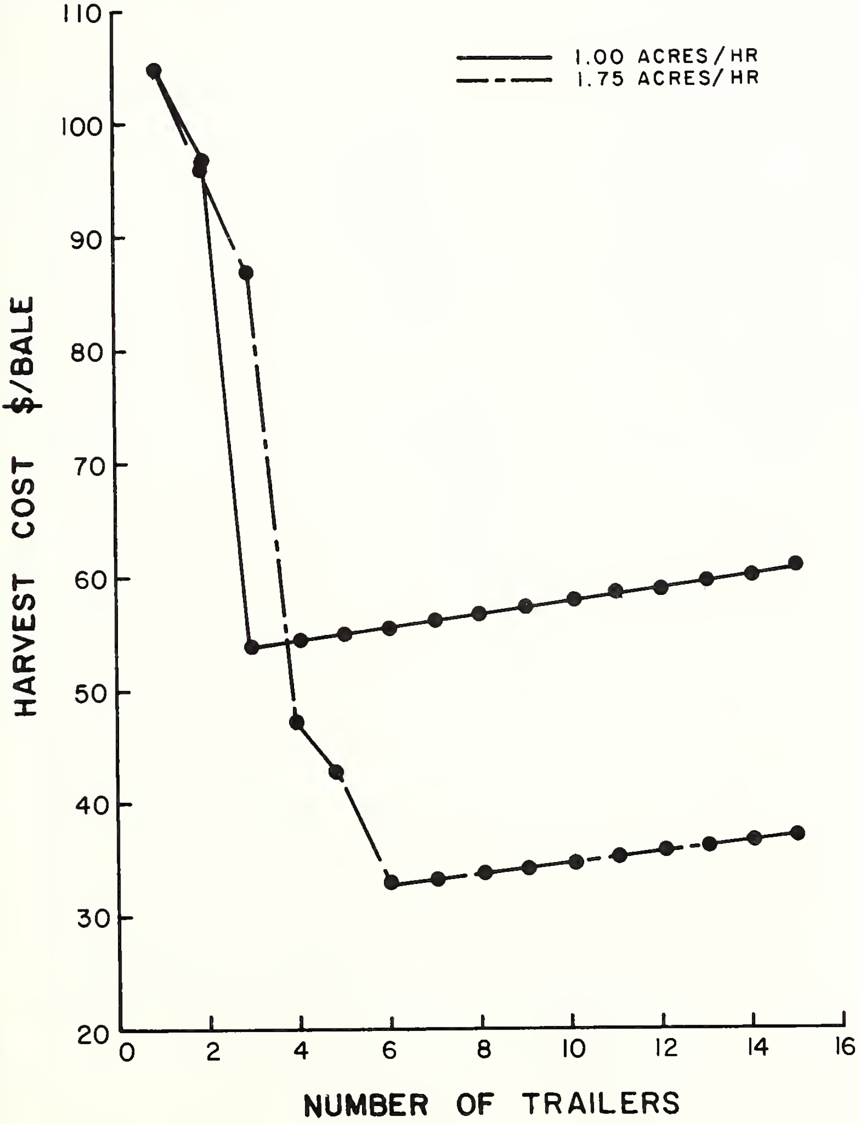

Figure 3.—Effect of picking rate on harvest cost. (400-acre farm, 10-bale trailers, 1 picker, 48-hr gin time.)

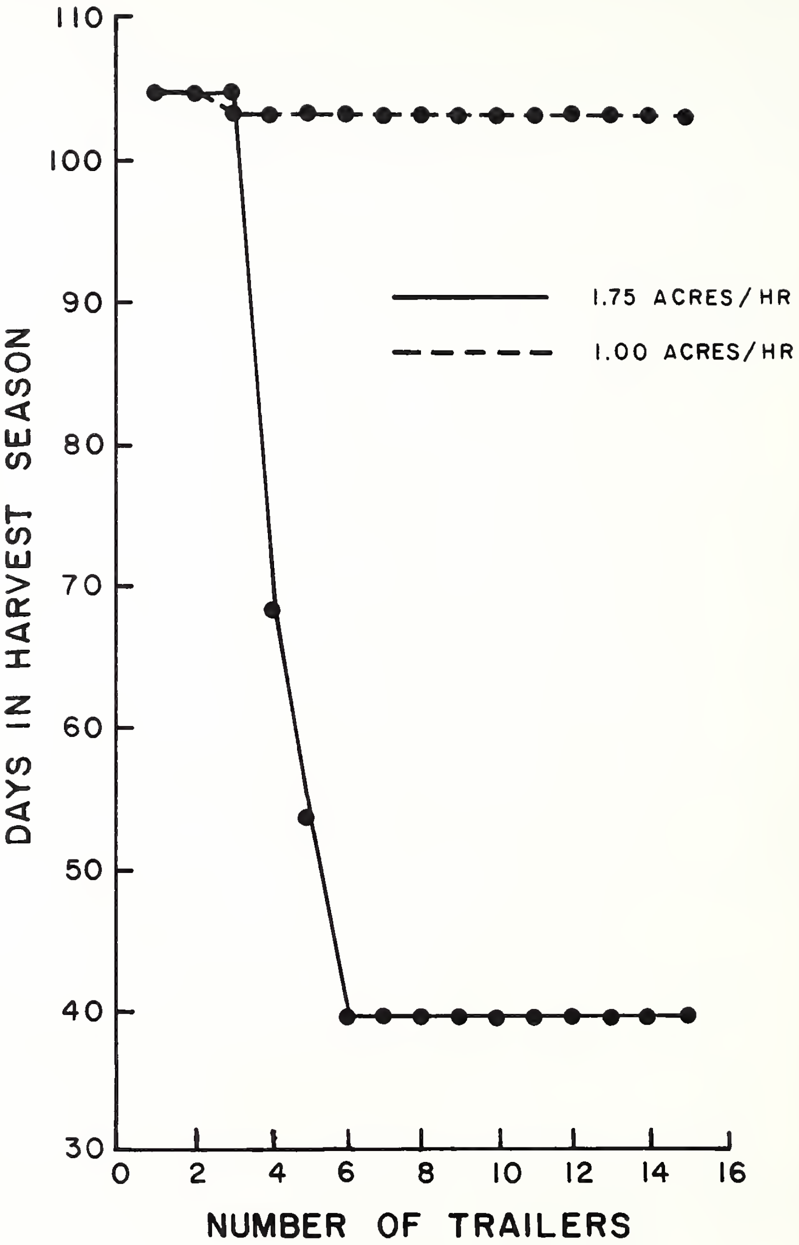

Figure 4.—Effect of picking rate on harvest season length. (400-acre farm, 10-bale trailers, 1 picker, 48-hr gin time.)

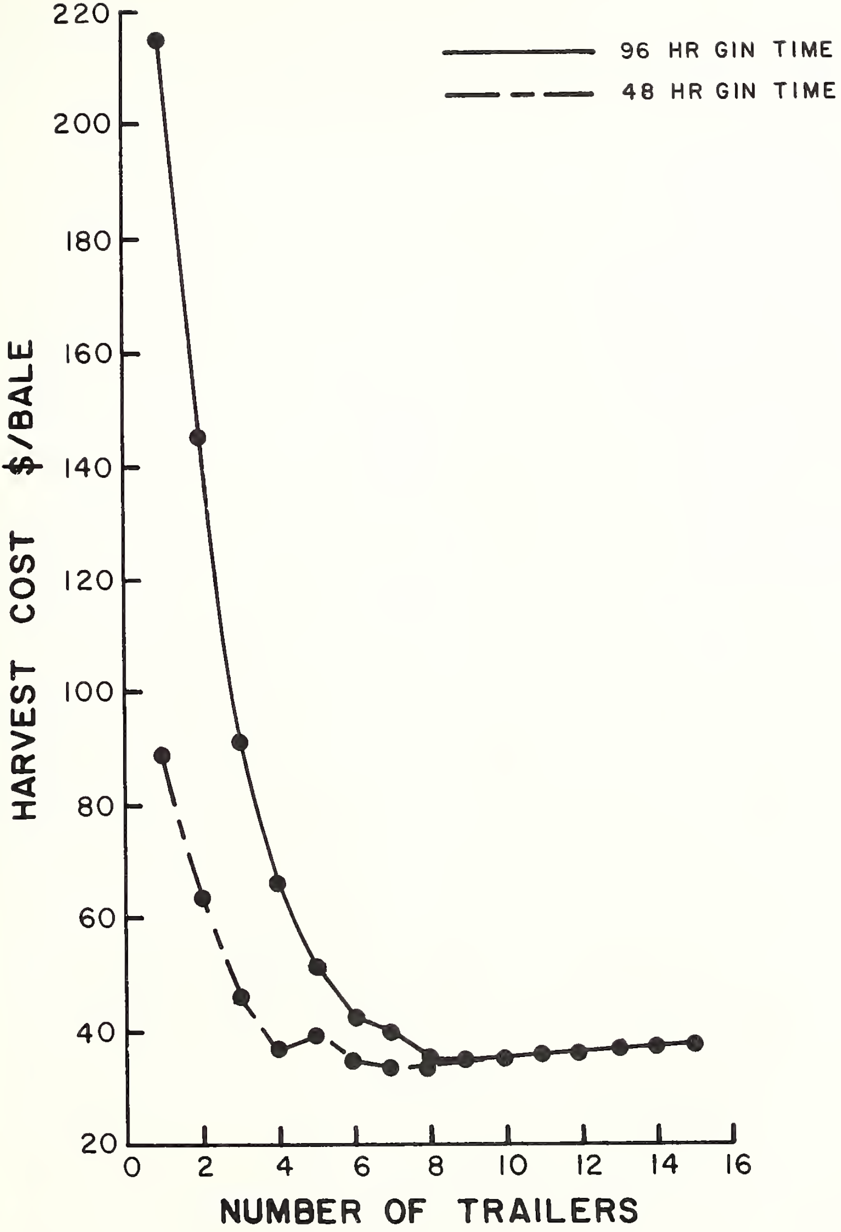

Figure 5.—Effect of gin time on harvest cost. (400-acre farm, 7-bale trailers, 1 picker with 1.75 acre/hr rate.)

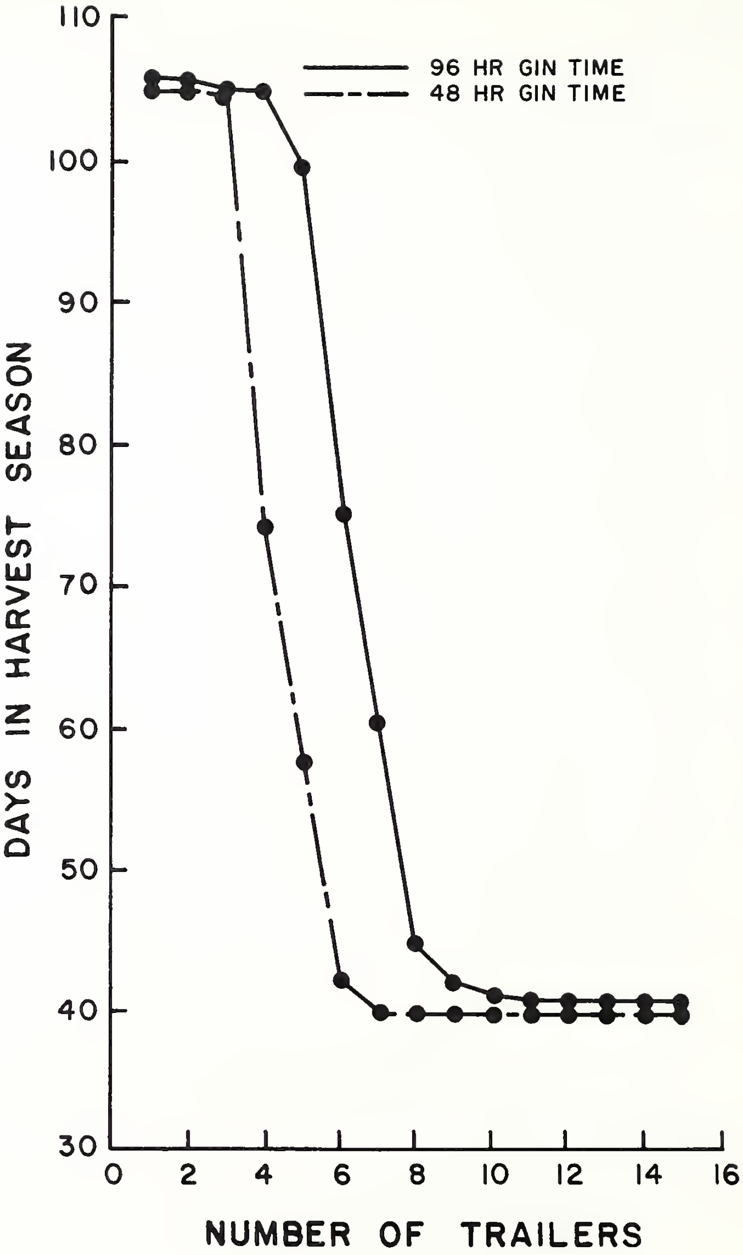

Figure 6.—Effect of gin time on harvest season length. (400-acre farm, 7-bale trailers, 1 picker with 1.75 acre/hr rate.)

of .75, 1, and 1.5 bales per acre (Figures 9 and 10). As yield increased, more trailers were needed for best performance. The number of trailers for optimum performance increased from four with a .75 bale per acre yield to eight for a 1.5 bales per acre yield.

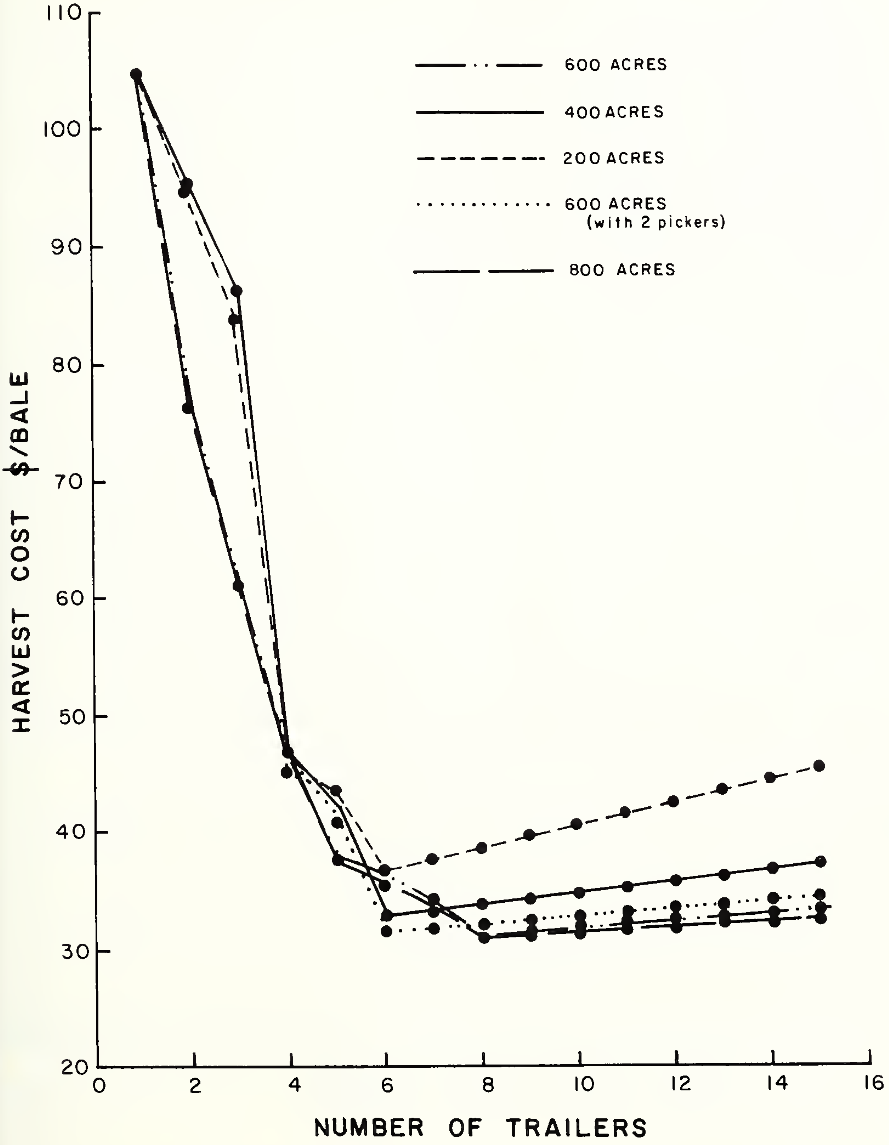

Figure 7.—Effect of farm size on harvest cost. (10-bale trailers, 1 picker with 1.75 acre/hr rate, 2 pickers with 3.50 acre/hr rate, 48-hr gin time.)

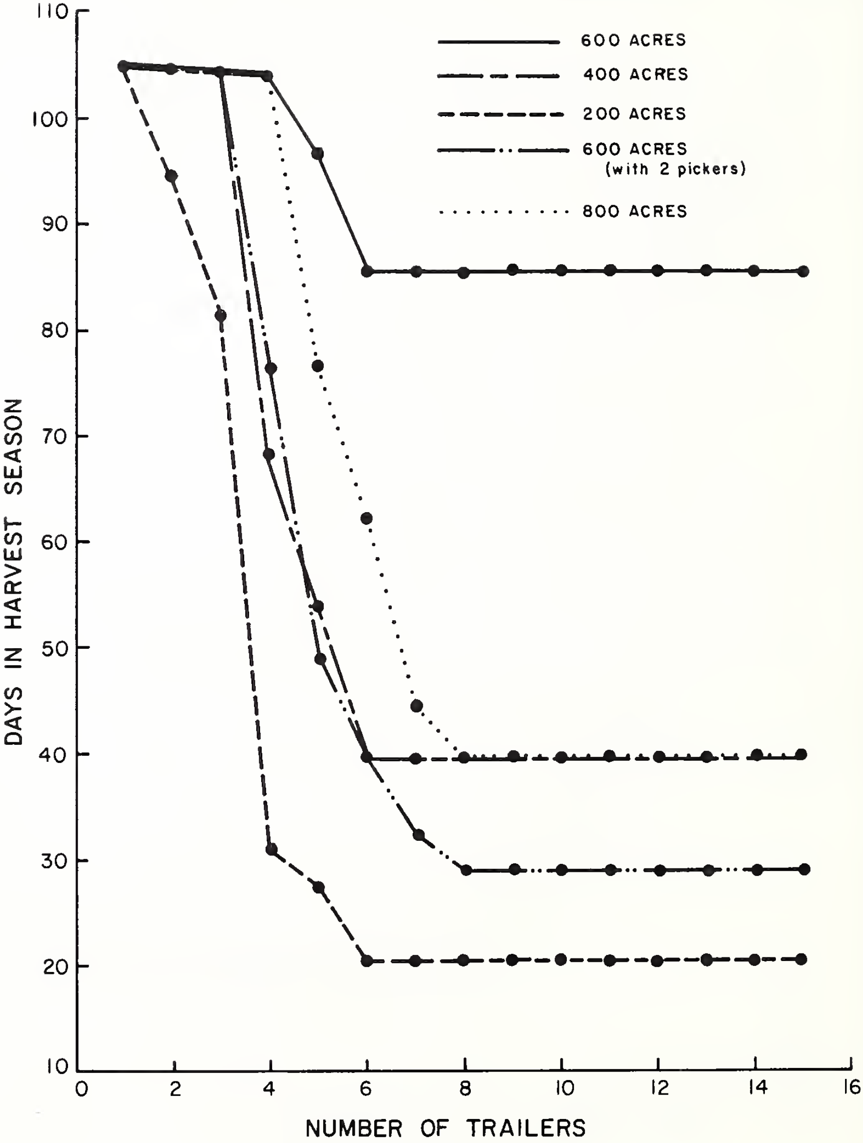

Figure 8.—Effect of farm size on harvest season length. (10-bale trailers, 1 picker with 1.75 acre/hr rate, 2 pickers with 3.50 acre/hr rate, 48-hr gin time.)

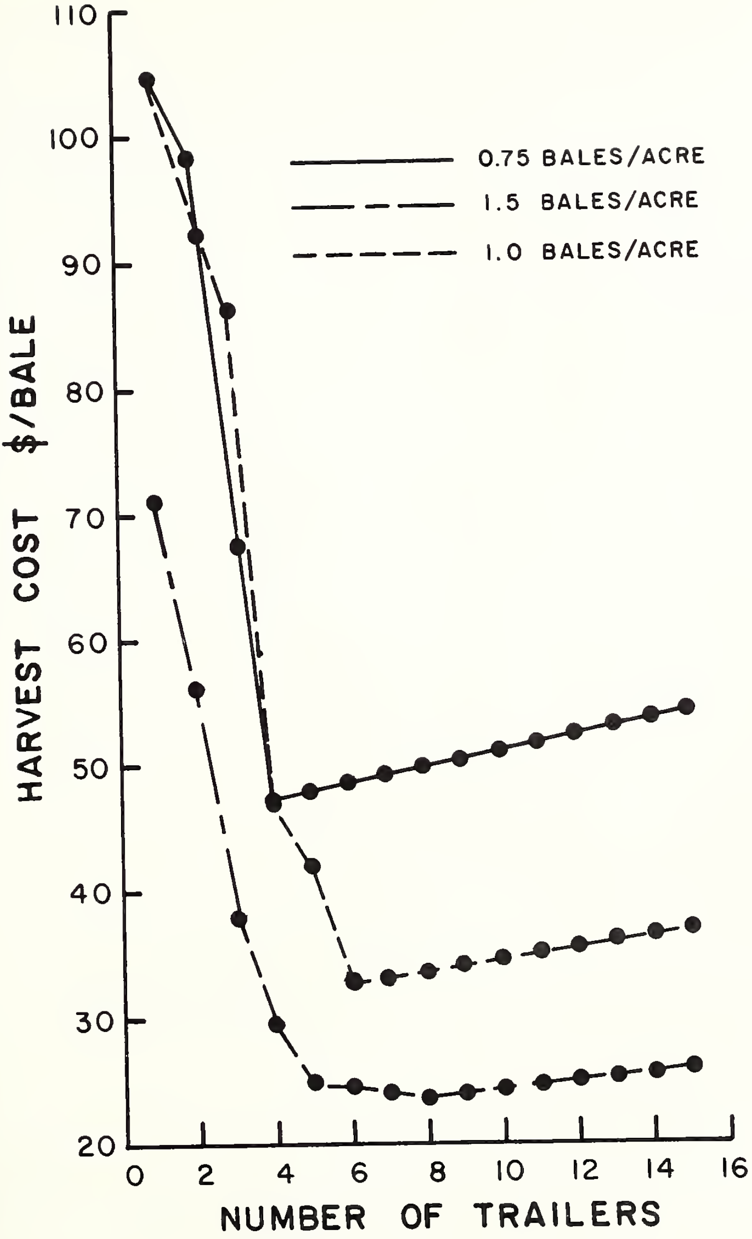

Figure 9.—Effect of yield on harvest cost. (400-acre farm, 10-bale trailers, 1 picker with 1.75 acre/hr rate, 48-hr gin time.)

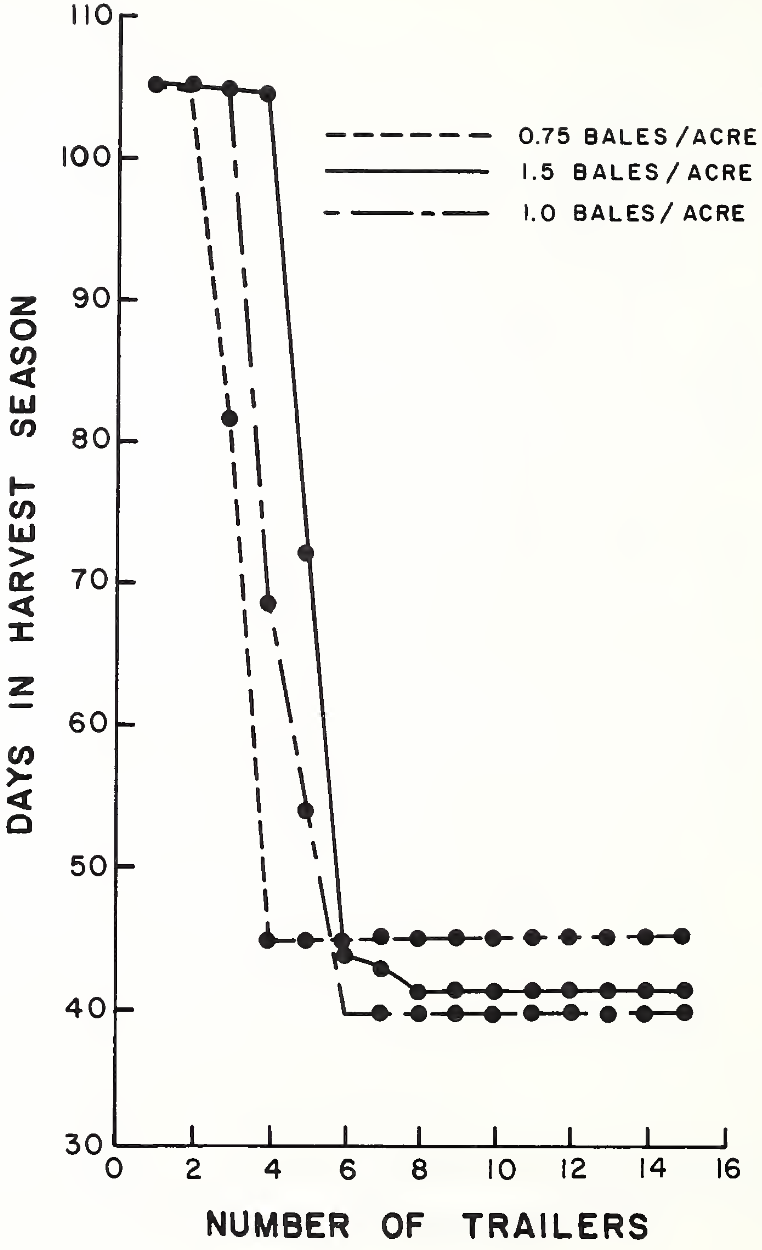

Figure 10.—Effect of yield on harvest season length. (400-acre farm, 10-bale trailers, 1 picker with 1.75 acre/hr rate, 48-hr gin time.)

Summary

Increasing the number of trailers increased the delivery rate of cotton to the gin until the system was limited by the picking rate. The least-cost point was always where the picking rate limited the delivery rate to the gin. Extra trailers added past the least-cost number increased the harvest cost very slightly. This indicates the additional cost of an extra trailer or two as insurance against bad weather or gin breakdowns would be a sound investment.

According to Paxton *(5)*, the projected 1979 harvest costs for Louisiana ranged from $28.98 to $45.98 per acre. Using projected costs and statistics for 1978, the model predicted harvesting costs of approximately $34.00 per acre.

Conclusions

1. The picker must be kept busy for a low-cost harvesting operation.
2. A one-picker system requires at least six 10-bale trailers.
3. A two-picker system requires at least eight 10-bale trailers.
4. One or two trailers more than the least-cost number of trailers will not drastically increase harvest costs and may be a sound investment as insurance against unusually bad weather and gin breakdowns.

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Bulletin No. 737

The Educational and Occupational Aspirations of Louisiana Rural High School Students: A Comparative Study

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The Educational and Occupational Aspirations of Louisiana Rural High School Seniors: A Comparative Study

GEORGE W. OHLENDORF AND DONNA M. RAFFERTY[1]

Introduction

During the past two decades, several studies have been conducted on the educational and occupational aspirations of rural youth. This research was stimulated by the contention that rural youth had lower aspirations than urban youth and, consequently, could not compete effectively for jobs in the urban labor market (Lipset, 1955; Sewell and Orenstein, 1965).

Studies of aspirations conducted in various places have produced findings indicating that rural youth generally had lower aspirations than urban youth. These findings suggested that research was needed on the consistency of aspirations among rural youth throughout the United States and on the stability of aspirations of youth over time. It is not clear whether aspirations of youth are affected by the socialization processes they experience.

The general objective of this study was to compare the educational and occupational aspirations of two cohorts (age groups) of Louisiana rural high school seniors—the classes of 1968 and 1972—and to compare the 1972 Louisiana cohort with a regional and national counterpart. The first specific aim was to ascertain whether the aspirations of seniors from Louisiana rural high schools in 1968 differed significantly from the aspirations of seniors in the same or similar schools in 1972. The second specific goal of the study included two parts: first, to compare the aspirations of the 1972 Louisiana rural students with a sample of students from the southern states; and second, to compare Louisiana students with a national sample in terms of their educational and occupational aspirations.

The research conducted was unique in that it involved comparisons between state, regional, and national sample populations during the same year. It also provided the opportunity to determine whether the aspirations of rural youth from the same area remained stable over time. The data collected were from both black and white respondents and from respondents of both sexes.

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Frame of Reference

This study, as noted, deals with the concept of aspiration. Specifically, it is concerned with level of educational aspiration and level of occupational aspiration. It was conceptualized that aspirations are acquired through the socialization process and that this process would change in response to location and time. The latter was seen as providing a perspective for the study of stability or change in aspirations.

Aspiration

Aspiration was viewed as a special type of attitude, one which involved a favorable orientation toward a goal. In light of this definition, aspirations were operationalized as the desired future ends or goals which students sought.

In elaborating the concept of aspiration, it is appropriate to point out that the choice of an occupation in American society is not an easy task because there are over 20,000 different occupations (McNeil, 1969:223). Most of the occupations require specific types of education for entry, and individual decisions about education and careers tend to be made during the high school years. Hence, the student decides on the type of job he or she wants and pursues the formal education necessary to get the job. These decisions are indicators of both educational aspiration and occupational aspiration.

Level of occupational aspiration is an extension of the general concept of aspiration. It involves perception of self relative to a particular level in the prestige hierarchy represented by the occupation. This particular orientation toward an occupation serves to channel action toward attainment of an occupational goal. A favorable attitude toward achieving the education necessary for an occupational goal is an indicator of level of educational aspiration.

Time

Historical events may influence the attitudes, beliefs, and goals of people in a society at any given time. The impact of time thus needs to be considered in studies of aspirations. Since values of the larger society influence the development of aspirations among adolescents, any study of the aspirations of youth must consider the values popular at the time. In this study, it was important that the social activism of the 1960's and 1970's be taken into consideration in assessing the aspirations expressed by high school students.

Location

The extent to which value orientations vary from one region to another is also of importance in studying aspirations of youth. In this study, it was of particular interest to determine whether the aspirations of rural youth in

Louisiana differed from rural youth elsewhere. This question was considered especially pertinent because of the notion that rural youth would be less likely to be affected by social movements such as occurred in the 1960's.

Hypotheses

The hypotheses that follow were designed in accordance with the objectives of the study.

Hypothesis 1: In selected Louisiana rural high schools, the educational aspirations of the senior students of 1972 will be significantly different from those of the senior students of 1968 for each sex and race combination.

Hypothesis 2: In selected Louisiana rural high schools, the occupational aspirations of the senior students of 1972 will be significantly different from those of the senior students of 1968 for each sex and race combination.

Hypothesis 3: The educational aspirations of the senior students of 1972 in selected Louisiana high schools will not differ significantly from those of senior students of 1972 in selected rural high schools in the southern region.

Hypothesis 4: The occupational aspirations of the senior students of 1972 in selected Louisiana rural high schools will not differ significantly from those of senior students of 1972 in selected rural high schools in the southern region.

Hypothesis 5: The educational aspirations of the senior students of 1972 in selected Louisiana rural high schools will not differ significantly from those of senior students of 1972 in selected rural high schools in other parts of the United States.

Hypothesis 6: The occupational aspirations of the senior students of 1972 in selected Louisiana rural high schools will not differ significantly from those of the senior students of 1972 in selected rural high schools in other parts of the United States.

Research Procedures

Source and Collection of Data

Data used in this study were obtained from two separate research projects—the Southern Youth Study (SYS) and the National Longitudinal Study of the High School Class of 1972.

Southern Youth Study. The first project, known as the SYS—project S-114 and its predecessors, S-61 and S-81—is a longitudinal study of rural youth supported by the U.S. Department of Agriculture and the Louisiana Agricultural Experiment Station. The research for the project was done in cooperation with the agricultural experiment stations of five other southern states. Information on the first cohort was collected in 1968 and on the second in 1972.

A proportionate, stratified, random cluster sampling technique was employed to obtain a representative sample of rural high school youth in Louisiana. The following procedure was used to select the sample: (1) The state was divided into geographical quadrants to represent four areas which differ in social and economic characteristics. (2) Schools were designated as the sampling units. Four to six schools were selected randomly from the nonmetropolitan parishes of each quadrant. To obtain a representative sample of both black and white students in proportion to the enrollment of nonmetropolitan students within the state, a total of 20 schools was selected, 13 white and 7 black. (3) The questionnaire was administered to all senior students present in school on the day of the survey.

In 1972, an effort was made to collect data from the same schools as in 1968. This could not be done in all instances because of changes that had taken place in the schools. In the desegregation process, many Louisiana high schools were combined, some old ones closed, and some new ones opened.

Only four of the original 20 schools—three white and one black—were substantially the same as in 1968. These four schools, the previously segregated schools that had been desegregated, and two private academies were selected as the sampling units in 1972. The private academies were selected because some students who would normally have been attending the public schools were enrolled in them. Although all seniors present on the day of the survey completed questionnaires, only students of the race predominant in the corresponding 1968 school were used in the analysis. This was done in an attempt to test only those respondents who would have been seniors in 1972 in the original 20 schools. To the degree possible, this filtering of the 1972 respondents assures that the 1968 and 1972 samples were comparable. Several social background characteristics of the two samples were tested to verify comparability. No significant differences were found in mother's education, father's education, or major money earner's occupation.

Data for the SYS in 1968 were collected by means of group interviews in the schools during early April. These interviews were conducted by staff members (faculty and graduate assistants) from the Department of Rural Sociology at Louisiana State University, who had been instructed in interview procedures prior to the field work. Approximately one hour was required for each interview. A total of 544 completed questionnaires were obtained—325 from whites, 218 from blacks, and one from a Native American. The detailed distribution of respondents by area and school is provided in the appendix.

A slightly modified version of the 1968 questionnaire was used in 1972. During May, this questionnaire was administered to the senior classes.

Completed questionnaires were obtained from 453 seniors in the schools. A mailed questionnaire was used for one private academy because the school year had concluded too early for the questionnaire to be administered at school. This academy had 19 graduates, 17 of whom returned their questionnaires. The distribution of respondents by area and school is provided in the appendix.

National Longitudinal Study. The second project from which data were utilized is the National Longitudinal Study (NLS) of the High School Class of 1972. This study is part of a long-term survey effort supported by the National Center for Education Statistics (NCES) in the former U.S. Department of Health, Education, and Welfare (Levinsohn et al., 1978). The NLS study was designed to provide statistics on a national cohort of students going through the process of leaving the school system and entering adult life.

In the NLS, the sampling design is a stratified two-stage probability sample with schools as the first-stage sampling units and students as the second-stage units. The sampling population was determined as all 1972 twelfth grade students enrolled in all public, private, and church-affiliated high schools in the 50 states and the District of Columbia.

The school sampling frame was stratified into 600 final strata according to the following criteria: (1) type of institution (public, nonpublic); (2) geographic region (northeast, north central, south, west); (3) senior enrollment (<300, 300-599, ≥600); (4) proximity to institutions of higher learning; (5) percent minority enrolled; (6) income level of the community; (7) degree of urbanization.

A representative sample of the schools was drawn. In order to increase the number of disadvantaged students, schools located in low-income areas and schools with high proportions of minority group enrollment were sampled at approximately twice the rate used for the remaining schools.

The NLS sample design called for the selection of 1,200 primary sample schools with 18 students per school participating in the survey. Of these 1,200 schools, 948 participated, 21 had no seniors enrolled, and 231 had either refused to participate or could not participate.

Because of this high rate of nonresponse in the base-year survey, the NCES attempted to resurvey the 231 nonparticipant schools and to survey replacements for the 21 schools with no seniors. Of the 231 primary sample schools, 205 participated in the resurvey with up to 18 former students being randomly selected from the 1972 graduating class. Students from substitute schools were also included in the base-year survey. In all, data were collected from students representing 1,069 participating schools in the base-year study.

The bulk of the student data was collected in April, May, and June of

1972 through group completion of questionnaires in each school. Information was collected from a total of 22,652 students, but only the 4,738 students in rural or farming communities were used as respondents in this study.

Operationalization of Variables

Six variables—four independent and two dependent—were used in this study. The independent variables are sex, race, year, and location; educational aspiration and occupational aspiration are the dependent variables. These variables were operationally defined by questionnaire items answered by the respondents. The specific questions used are provided in the appendix.

Educational aspiration was determined by the response the student gave to the education he or she desired: quit high school, complete high school, complete a business or technical program, graduate from junior college, graduate from college, or complete additional studies after college. These were assigned scores from 1 through 6, respectively.

Occupational aspiration was defined in terms of the student's response to the kind of job he or she would like to have. The questionnaire items differed slightly between the SYS and the NLS so the data from both studies were recoded using slightly modified Bureau of the Census occupational groupings. Categories used were: professional, technical, manager, farmer/farm manager, clerical, sales, military (officer or enlisted), craftsman/skilled craftsman, operative, service and labor, and homemaker/housewife. Numerical values ranging between 1 and 11 were assigned inversely to these categories.

Residence in this study included only rural students. Respondents were asked to choose an answer which best described the place in which they lived. The questionnaire items in the SYS and the NLS varied. To account for this discrepancy, only NLS students who answered that they lived in a rural or farming community were used as rural seniors. All respondents in the SYS were used even though six students responded that they had lived previously in a city of 2,500 or greater. This was done because the next category of the NLS question included students who lived in cities of up to 50,000 population.

Region was used to define students from the South according to the Census definition for this region (Levinsohn et al., 1978:G.1).

Analytical Technique

Analysis of variance (ANOVA) was selected as the statistical test to determine if any significant differences in aspirations existed between the groups of students with respect to sex, race, year, and location.[2] The general linear model was used because of the relatively large sample and the unbalanced design.

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[2] See Appendix B for comments on the use of ANOVA in this study.

Analysis and Interpretation

Changes in student aspirations over time (Hypotheses 1 and 2) are analyzed first; this is followed by analysis of differences in student aspirations between locations (Hypotheses 3-6).

Time—1968 to 1972

In this section, the hypothesized relationships presented earlier are tested for change in aspirations over time for each race and sex combination.

Educational aspirations. Significant differences in educational aspirations between the 1968 and 1972 classes of Louisiana rural high school seniors are evident in the ANOVA summary table and the means presented in Table 1. The educational aspirations of the 1968 rural high school

Table 1.—Analysis of variance and means for educational aspirations of Louisiana rural high school seniors in 1968 and 1972, by race and sex

ANOVA Summary Table

Source	Degrees of freedom	Sum of squares	F ratio
TOTAL	987	2,022.59	
Year	1	24.54	12.17**
Sex	1	0.11	0.05
Race	1	10.80	5.36*
Year x Sex	1	0.44	0.22
Year x Race	1	2.72	1.35
Sex x Race	1	2.48	1.23
Year x Sex x Race	1	1.06	0.52
ERROR	980	1,975.35	

Race x Sex	Year 1968	Year 1972
	Means	Means
White Male	4.38 N=167	4.27 N=149
White Female	4.36 N=157	4.02 N=161
Black Male	4.67 N=89	4.20 N=64
Black Female	4.73 N=124	4.31 N=77

*P<.05
**P<.01

seniors were higher (4.50) than those of the 1972 rural high school seniors (4.18). This finding suggests that social activism in the late 1960's and early 1970's did not result in higher aspirations among these rural students during this four-year interval.

There was also a difference in aspirations between rural black students and rural white students. Rural black students had higher educational aspirations than the rural white students (4.53 and 4.26, respectively). There was little difference in educational aspirations between male students (4.38) and female students (4.34).

Overall, rural black female seniors of the class of 1968 had the highest educational aspirations. This finding is consistent with earlier studies (Coleman, 1976). Rural black male students had the second highest level of aspiration, while rural white male and female students had equivalent educational aspirations. These findings are also supportive of earlier research (see Clay, 1976 and Coleman, 1976).

In 1972, the educational aspirations of rural high school seniors had dropped markedly compared with those of the class of 1968. This is contrary to the findings of Clay (1976) that, overall, the aspirations of students rise over time. Again, black female students had the highest aspirations, but white males held the second highest level of aspiration. Black males and white females had lower educational aspirations. The low white female aspirations are contrary to Clay's findings in an Ontonogan County, Michigan study.

Occupational aspirations. The occupational aspirations of the senior class of 1972 were significantly different from those of the senior class of 1968 (Table 2). The rural seniors of 1968 had higher aspirations than did the rural seniors of 1972 (8.43 and 8.06, respectively). Again, this finding is inconsistent with most previous studies in which student aspirations increased over time. There was also a difference between the sexes. Female senior students (8.68) had much higher occupational aspirations than male students (7.79). Little difference in occupational aspirations was found between black students (8.36) and white students (8.21).

Rural black female students had the highest occupational aspirations in 1968. White females had the second highest level of aspiration, while rural black male students and white male students had the lowest occupational aspirations. This is consistent with the findings of Kuvlesky and Edington (1976).

In 1972 the level of occupational aspiration of rural seniors had declined for each race and sex combination. White females had the highest aspirations. Black males and black females aspired to nearly the same levels of occupation. The decline in aspirations of black females was the greatest of this group. Again white males had the lowest occupational aspirations.

Table 2.—Analysis of variance and means for occupational aspirations of Louisiana rural high school seniors in 1968 and 1972, by race and sex

ANOVA Summary Table

Source	Degrees of freedom	Sum of squares	F ratio
TOTAL	960	8,279.92	
Year	1	39.18	4.66*
Sex	1	125.06	14.86**
Race	1	0.39	0.05
Year x Sex	1	12.77	1.52
Year x Race	1	8.14	0.97
Sex x Race	1	14.92	1.77
Year x Sex x Race	1	0.91	0.11
ERROR	953	8,020.67	

Race x Sex	Year	
	1968	1972
	Means	
White Male	7.71 N=165	7.65 N=142
White Female	8.93 N=154	8.51 N=160
Black Male	8.15 N=80	7.83 N=60
Black Female	8.97 N=124	8.03 N=76

*P<.05
**P<.01

Location—Southern Region vs. Louisiana

Comparisons between the southern region rural sample from the NLS and the Louisiana rural sample of the SYS are made in this section.

Educational aspirations. An inspection of Table 3 reveals a significant difference in educational aspirations between southern and Louisiana senior students in 1972. The southern region rural seniors had higher aspirations (4.43) than the Louisiana rural seniors (4.18), and male seniors had higher aspirations (4.48) than female seniors (4.21).

There was virtually no effect of race on the educational aspirations of black students (4.37) and white students (4.33). Rural white males and rural black males of the southern region had equivalent aspirations. Rural black females of the southern region had much higher aspirations than rural white females of the region.

Table 3.—Analysis of variance and means for educational aspirations of southern rural high school seniors and Louisiana rural high school seniors in 1972, by race and sex

ANOVA Summary Table

Source	Degrees of freedom	Sum of squares	F ratio
TOTAL	1,173	2,365.44	
Location	1	14.05	7.07**
Sex	1	3.60	1.81
Race	1	2.45	1.23
Location x Sex	1	1.21	0.56
Location x Race	1	0.04	0.02
Sex x Race	1	3.80	1.91
Location x Sex x Race	1	0.06	0.03
ERROR	1,166	2,316.82	

Race x Sex	Location Southern	 Louisiana
	--Means--	
White Male	4.62 N=296	4.27 N=149
White Female	4.24 N=355	4.02 N=161
Black Male	4.62 N=32	4.20 N=64
Black Female	4.52 N=40	4.31 N=77

*P<.05
**P<.01

The black female seniors in Louisiana rural high schools had the highest aspirations. As was true for the regional sample, rural white males and rural black males were similar in their levels of educational aspirations, and rural white females of the Louisiana sample had the lowest educational aspirations. These low white female aspirations might be attributed to the traditional belief that young rural women just graduated from high school are supposed to get married and start a family or get a job working in the clerical or sales area.

Occupational aspirations. No evidence was found of significant effects of location or race on the occupational aspirations of the seniors in the southern region or the seniors in Louisiana, but a slight difference between the sexes was noted (Table 4). The Louisiana rural seniors had slightly higher aspirations than the southern region rural seniors (8.06 and 7.87, respectively). The occupational aspirations of male students (7.75) were lower than those of female students (8.10). Overall, there was no difference detected between black students and white students, both groups having equivalent occupational aspirations (7.95 and 7.94, respectively).

Table 4.—Analysis of variance and means for occupational aspirations of southern rural high school seniors and Louisiana rural high school seniors in 1972, by race and sex

ANOVA Summary Table

Source	Degrees of freedom	Sum of squares	F ratio
TOTAL	1,160	11,582.90	
Location	1	2.13	0.21
Sex	1	39.84	4.00*
Race	1	0.28	0.03
Location x Sex	1	0.02	0.00
Location x Race	1	1.86	0.19
Sex x Race	1	0.21	0.02
Location x Sex x Race	1	20.66	2.07
ERROR	1,153	11,497.26	

Race x Sex	Location	
	Southern	Louisiana
	Means	
White Male	7.81 N=296	7.65 N=142
White Female	7.90 N=355	8.51 N=160
Black Male	7.47 N=32	7.83 N=60
Black Female	8.38 N=40	8.03 N=76

*P<.05
**P<.01

Rural black female seniors from the southern region had the highest level of aspiration for their group. White males had the second highest level of aspiration, and rural white females had much higher occupational aspirations than black males of the southern region.

In contrast to the regional data, rural white females in Louisiana had the highest occupational aspirations. Black male and black female students had comparable levels of occupational aspiration, and rural white males had the lowest aspirations.

Location: United States vs. Louisiana

Educational Aspirations. Table 5 discloses a statistically significant difference in educational aspirations between the 1972 rural high school seniors in the United States and those in Louisiana. The national senior students had higher educational aspirations (4.41) than did the Louisiana seniors (4.18), and the aspirations of male students (4.48) were higher than those of female students (4.26). There was virtually no difference between the black and the white students in level of educational aspiration (4.38 and 4.37, respectively).

Rural black male students of the national sample had the highest educational aspirations. Rural white males and rural black females had comparable educational aspirations, while rural white females had the lowest educational aspirations. These findings are supportive of the literature

Table 5.—Analysis of variance and means for educational aspirations of United States rural high school seniors and Louisiana rural high school seniors in 1972, by race and sex

ANOVA Summary Table

Source	Degrees of freedom	Sum of squares	F ratio
TOTAL	2,463	4,682.87	
Location	1	15.12	8.03**
Sex	1	4.21	2.24
Race	1	3.70	1.96
Location x Sex	1	1.38	0.73
Location x Race	1	0.23	0.12
Sex x Race	1	1.18	0.63
Location x Sex x Race	1	1.45	0.77
ERROR	2,456	4,625.56	

Race x Sex	Location	
	United States	Louisiana
	Means	
White Male	4.53 N=920	4.27 N=149
White Female	4.29 N=1014	4.02 N=161
Black Male	4.72 N=36	4.20 N=64
Black Female	4.46 N=43	4.31 N=77

*P<.05
**P<.01

dealing with educational aspirations—see Kuvlesky and Boykin (1977) and Clay (1976).

In contrast to the national sample, the rural black females of the Louisiana sample had the highest aspirations. Rural white males had roughly the same level of educational aspiration, and rural black males were only slightly lower. Again, the rural white females had the lowest educational aspirations.

Occupational aspirations. An examination of Table 6 reveals a slight difference in the occupational aspirations of the 1972 rural high school seniors in the United States and Louisiana. Aspirations of the national rural seniors (7.67) were slightly lower than those of Louisiana rural seniors (8.06). There were differences in aspirations between male and female students (7.48 and 7.97, respectively). Black students (8.00) and white students (7.72) had comparable levels of aspiration.

Table 6.—Analysis of variance and means for occupational aspirations of United States rural high school seniors and Louisiana rural high school seniors in 1972, by race and sex

ANOVA Summary Table

Source	Degrees of freedom	Sum of squares	F ratio
TOTAL	2,450	27,802.97	
Location	1	3.46	0.31
Sex	1	50.77	4.50*
Race	1	3.38	0.30
Location x Sex	1	0.12	0.01
Location x Race	1	14.62	1.30
Sex x Race	1	1.54	0.14
Location x Sex x Race	1	9.26	0.82
ERROR	2,443	27,570.64	

Race x Sex	Location	
	United States	Louisiana
	Means	
White Male	7.42 N=920	7.65 N=142
White Female	7.86 N=1014	8.51 N=160
Black Male	7.72 N=36	7.83 N=60
Black Female	8.44 N=43	8.03 N=76

*P<.05
**P<.01

Rural black females in the national sample had the highest aspirations of their group. Rural white females and rural black males had comparable levels of occupational aspiration. This finding is consistent with those of Coleman (1976).

Of the Louisiana sample, rural white females had the highest occupational aspirations. This is supportive of Clay's 1976 follow-up study in Ontonogan County, Michigan. Black male and black female seniors had similar levels of aspiration. Again, as in the national sample, rural white males had the lowest occupational aspirations.

Summary of Results

In summary, the educational and occupational aspirations of 1972 Louisiana rural high school seniors decreased in comparison to those of the 1968 seniors. This finding suggests that social events which occurred during the years that the 1972 seniors were in high school did not have a positive effect on their aspirations.

There was a significant difference in educational aspirations between 1972 rural high school seniors from Louisiana and those from the southern region. The southern students aspired to much higher levels of education than did the Louisiana seniors. There was no evidence of a significant effect of location on the occupational aspirations of these students.

Significant differences in educational aspirations were found between rural high school seniors in the United States and in Louisiana, but only a slight effect of location was found on the occupational aspirations of the students.

Summary and Implications

The purpose of this study was to contribute to further understanding of the aspirations of rural high school seniors. Specifically, emphasis was placed on the educational and occupational aspirations of Louisiana rural seniors during 1968 and 1972 and on rural seniors in 1972 from throughout the United States and the South. The variables time and location as well as sex and race were tested to ascertain whether these groups of students differed in their educational and occupational aspirations. Two effects—time and location—were significant on levels of aspiration. The educational and occupational aspirations of the 1972 Louisiana rural high school seniors decreased in comparison to those of 1968 seniors. Educational aspirations of the 1972 rural seniors from Louisiana were significantly lower than those of both the southern region and the United States. In each instance, the marginals showed that these differences for the Louisiana rural seniors in 1972 occurred throughout the range of each respective aspirational variable and were not confined to any single or dual categories.

The findings suggest that educational aspirations are affected more by time and geographic location than occupational aspirations are.

The first major finding of this study was that the seniors of 1972 from Louisiana rural high schools had lower educational aspirations than 1968 Louisiana rural high school seniors, 1972 southern rural high school seniors, and United States rural high school seniors in 1972. The finding has significance for educational programs as well as for aspiration theory. Since Louisiana is part of the Sunbelt, a region with abundant employment opportunities, Louisiana rural youth may have become more strongly oriented toward employment opportunities than toward further education. This is supported by the concurrent decline in occupational aspirations, indicating a desire for jobs with lower educational requirements. However, many of the ''better'' jobs that are being created through industrialization in this region require more formal education, so attaining the education to qualify for these jobs will become more important to future high school seniors.

Rural white females from Louisiana consistently had higher occupational aspirations than all other students. This may be attributed to the fact that two traditional female occupations to which many white females in the state have been attracted, nurse and teacher, are included as professional occupations, thus giving white females an overall higher occupational aspiration.

The findings of this study contribute to better understanding of the educational and occupational aspirations of rural white and rural black high school seniors. It was found, for example, that the educational and occupational aspirations of Louisiana rural high school seniors did not increase over time as was theorized. The fact that they decreased suggests that social time needs to be considered when studying the aspirations of comparable rural youth at different times or periods.

In this study, the differences in aspirations over time may be related to the social activism of the 1960's and 1970's when many youth were seeking alternative goals and means of fulfilling these goals. It has been suggested, in this regard, that the cultural revolution was centered generally in upper-middle class youth and that the college-educated children of lower-middle and working-class families face greater prospects for social mobility (Berger and Berger, 1971). At any rate, effect of social time on aspirations of youth needs to be studied with more inclusive populations over longer periods. Whether this decline in aspirations—both educational and occupational—has continued into the 1980's is of even greater interest and needs to be addressed in future research.

In concluding, attention should be directed toward the implications of this study. Some rural youth obviously are not abreast of the developments in education that will affect their immediate future. Although a great deal of attention has been devoted to improving the information available to rural youth, it is possible that both communication and counseling efforts have fallen short. Educators should be made aware of this fact.

In particular, the position of counselor has been established in many schools for the purpose of helping students make realistic decisions. Counselors need to be well informed about current developments with respect to education and employment, and they need to make rural young people aware of these developments. Until this is done, rural youth will continue to be disadvantaged with respect to urban employment opportunities. This is a challenge for school officials who serve rural communities.

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Appendix A

Excerpts from Research Instrument

2. Sex (Circle one number): 1 Male 2 Female

4. Where have you lived most of your life? (Circle one number):

1 Large city (50,000 and over)

2 Medium city (10,000 to 50,000)

3 Small city (2,500 to 10,000)

4 Town or village (under 2,500)

5 In the country, but not on a farm

6 On a farm

6. What is your race? (Circle one number):

1 White 2 Black 3 Oriental 4 Indian 5 Other

9. If you were completely free to choose any job, what would you desire most as a lifetime job? (In answering this question give an exact job. For example, do not say "work on the railroad" but tell us what railroad job you would like to have). Write your answer in the box below.

ANSWER:

13. If you could have as much schooling as you desired, which of the following would you do? (Circle only one number):

1 Quit school right now.
2 Complete high school.
3 Complete a business, commercial, electronics, or some other technical program after finishing high school.
4 Graduate from a junior college (2 years).
5 Graduate from a college or university.
6 Complete additional studies after graduating from a college or university.

Sex	(Circle one.)
Male	1
Female	2

Date of Birth		
Mo.	Day	Year

Please complete the information above.

* * *

84. How do you describe yourself?

	(Circle one.)
American Indian	1
Black or Afro-American or Negro	2
Mexican-American or Chicano	3
Puerto Rican	4
Other Latin-American origin	5
Oriental or Asian-American	6
White or Caucasian	7
Other	8

* * *

95. Which best describes the location of the place in which you live?

	(Circle one.)
In a rural or farming community	1
In a small city or town of fewer than 50,000 people that is not a suburb of a larger place	2
In a medium-sized city (50,000-100,000 people)	3
In a suburb of a medium-sized city	4
In a large city (100,000-500,000 people)	5
In a suburb of a large city	6
In a very large city (over 500,000 people)	7
In a suburb of a very large city	8

25. In the column under YOU, circle the one number that goes with the best description of the kind of work you would like to do. Under FATHER, circle the one number that best describes the work done by your father (or male guardian). Under MOTHER, circle the one number that best describes the work done by your mother (or female guardian). The exact job may not be listed but circle the one that comes closest. If either of your parents is out of work, disabled, retired, or deceased, mark the kind of work that he or she used to do.

(Circle one number in each column.)

	You	**Father**	**Mother**
CLERICAL such as bank teller, bookkeeper, secretary, typist, mail carrier, ticket agent	01	01	01
CRAFTSMAN such as baker, automobile mechanic, machinist, painter, plumber, telephone installer, carpenter	02	02	02
FARMER, FARM MANAGER	03	03	03
HOMEMAKER OR HOUSEWIFE	04	04	04
LABORER such as construction worker, car washer, sanitary worker, farm laborer	05	05	05
MANAGER, ADMINISTRATOR such as sales manager, office manager, school administrator, buyer, restaurant manager, government official	06	06	06
MILITARY such as career officer, enlisted man or woman in the armed forces	07	07	07
OPERATIVE such as meat cutter; assembler; machine operator; welder; taxicab, bus, or truck driver; gas station attendant	08	08	08
PROFESSIONAL such as accountant, artist, clergyman, dentist, physician, registered nurse, engineer, lawyer, librarian, teacher, writer, scientist, social worker, actor, actress	09	09	09
PROPRIETOR OR OWNER such as owner of a small business, contractor, restaurant owner	10	10	10
PROTECTIVE SERVICE such as detective, policeman or guard, sheriff, fireman	11	11	11
SALES such as salesman, sales clerk, advertising or insurance agent, real estate broker	12	12	12
SERVICE such as barber, beautician, practical nurse, private household worker, janitor, waiter	13	13	13
TECHNICAL such as draftsman, medical or dental technician, computer programmer	14	14	14

* * *

29. To answer this question, circle one number for the highest level of education you would like to attain, and also circle one for the highest level you plan to attain.

(Circle one number in each column.)

	Would like to attain	**Plan to attain**
Less than high school graduation	1	1
Graduate from high school but not go beyond that	2	2
Graduate from high school and then go to a vocational, technical, business, or trade school	3	3
Go to a junior college	4	4
Go to a four-year college or university	5	5
Go to a graduate or professional school *after college*	6	6

* * *

Table A-1.—Distribution of nonmetropolitan Louisiana senior respondents for 1968 and 1972, by area, school, race, and sex

	1968						1972					
	Black			White			Black			White		
Area & School	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total
Northwest												
J.S.Clark	7[a]	6	13[a]									
Zwolle High							5	4	9			
Ebarb				13	8	21				13	7	20
Georgetown				11	7	18				10	12	22
Second Ward	36	31	67				16	27	43			
Stanley				6	6	12				5	5	10
Verda				5	9	14						
Northeast												
Forest				13	10	23				16	20	36
Newellton				20	12	32				16	8	24
Rayville High	1		1	34	30	64				30	26	56
Riverfield Academy										5	7	12
Wisner-Gilbert	10	17	27									
Wisner High							9	13	22			
Southwest												
Bordelonville				5	12	17				5	5	10
Carver	23	34	57									
Bunkie Sr. High							7	13	20			
Cottonport				17	18	35				13	25	38
W.W. Stewart	2	14	16									
Basile							2	7	9			
Southeast												
E.Livingston High	6	12	18									
Springfield							10	4	14			
Holden				12	5	17				12	6	18
Livonia				10	17	27				9	14	23
Poydras				15	15	30				6	10	16
False River Academy										8	9	17
Romeville	1	2	3	8[b]	8	16[b]						
Romeville High (Boys)							14		14	2		2
Romeville High (Girls)								7	7		8	8
Scottville	6	10	16									
Belle Chasse							1	2	3			
TOTAL	92[a]	126	218[a]	169[b]	157	326[b]	64	77	141	150	162	312

[a] Includes 1 respondent whose questionnaire is missing.

[b] Includes 1 Native American.

Appendix B

It should be noted that use of ANOVA requires the assumption of interval level measurement of the dependent variable and that the dependent variables in this study—educational aspiration and occupational aspiration—do not fully meet this assumption. For education, the scores represent essentially 2-year increments except for the two middle categories. Since graduating from a junior college nearly always requires 2 full years and completing a business or technical program often takes less than this, the former was given the higher value.

The measure of occupational aspiration is a slight modification of occupational groupings used by the Bureau of the Census. These groups are ranked on the two dimensions of income and education with relatively high correspondence (Miller, 1977:244). Differences from the Census groupings in the measure used here include (1) addition of a classification for military between the white-collar and blue-collar segments, (2) addition of a category for homemaker and housewife as the final group, and (3) use of a separate classification for technical occupations (between professional and managers). Although the homemaker-housewife category usually is not considered to be an occupation, it is the only occupational status some women ever have; it was placed at the bottom because it has no income or earnings specifically associated with it and is usually not evaluated as an exciting and desirable life goal (Lopata, 1971:29-31, 138-148).

Statistical tests requiring assumption of interval-level measurement are used fairly routinely with ordinal-level measures that approximate interval-level ones because the tests are robust enough to be used with little fear of gross errors so long as the ordinal measure is monotonic (Bohrnstedt and Carter, 1971:131). The advantages of using the more powerful tests are well-known, and this increase in power makes the risk of errors in inference with them small in comparison with the more limited results of tests appropriate for ordinal-level measures.

The Louisiana Agricultural Experiment Station follows a nondiscriminatory policy in programs and employment.

Bulletin No. 738 June 1982

The Red Imported Fire Ant, *Solenopsis invicta* Buren:

Cultural Control and Effect on Hay Meadows

W.E. Blust, Bob H. Wilson,
K.L. Koonce, B.D. Nelson
and J.E. Sedberry, Jr.

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Cover Picture

The background picture on the front cover is a scanning electron micrograph of a red imported fire ant, *Solenopsis invicta*. The LSU Department of Entomology, Louisiana Agricultural Experiment Station, is a cooperating member of the Life Sciences Electron Microscopy Facility. (Photo by John Aubrey.) MAG. 70X.

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Preface

In the 40-year period since its introduction into the southeastern United States at Mobile, Alabama, no other insect has received as much publicity and created as much controversy in the southern United States as the red imported fire ant, *Solenopsis invicta* Buren. While extensive research has been conducted concerning this ant, the majority of work has focused on biology and chemical control. There have been few research efforts to assess the economic impact of the fire ant in agricultural ecosystems and to develop nonchemical control measures. The study reported here was conducted to gain more knowledge of the beneficial-detrimental relationships of the fire ant in pasture-meadow ecosystems so cost-benefit ratios of fire ant infestations could be more fully understood. Information on a noninsecticidal method of population suppression is also reported.

The research reported here is presented in three independent chapters. Chapter I includes results of a study designed to determine the effect of the fire ant on yield and quality of pasture grasses in Louisiana. Chapter II is devoted to results of a study designed to determine the effect of fire ant infestation on soil fertility in southern Louisiana. Chapter III deals with the efficacy of a noninsecticidal method of fire ant population suppression.

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THE RED IMPORTED FIRE ANT, *Solenopsis invicta* Buren: Cultural Control and Effect on Hay Meadows

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Chapter I: Effect of the Red Imported Fire Ant, *Solenopsis invicta* Buren, on Yield and Quality of Pasture Grasses in Louisiana

Abstract

A comparison of grass (bermudagrass, *Cynodon dactylon* (L.) Pers.—dallisgrass, *Paspalum dilatatum* Poir., mixture) grown in mirex-treated and untreated field plots showed that a 2.75X activity level of the red imported fire ant, *Solenopsis invicta* Buren, in untreated plots over treated plots did not affect ($P>.05$) yield or quality of the forage produced. Sweep net samples indicated that low populations of phytophagous and predaceous arthropods and several other species of invertebrates were present in the test area throughout the study. Differences in these populations between treatments were relatively small and were probably of no consequence in affecting yield or quality of the grass.

Introduction

The red imported fire ant, *Solenopsis invicta* Buren, is a common insect in Louisiana pasture ecosystems. Little is known, however, about its impact on forage production.

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Wilson (1969) found approximately twice as many leafhoppers in test plots where the red imported fire ant was eliminated as in plots where they were active. Later Hawkins et al. (1979) found that leafhoppers and planthoppers could significantly reduce yields of Coastal bermudagrass, *Cynodon dactylon* (L.) Pers. Other studies in Louisiana have shown that elimination of the fire ant from a given area results in a resurgent increase of other insect species (Newsom et al. 1959, Negm and Hensley 1967, Gross and Spink 1969, and Howard 1975).

The red imported fire ant is an opportunistic and omnivorous feeder, but feeds mainly on insects and other arthropods (Hays and Hays 1959, Wilson and Oliver 1969, and Howard 1975). Lofgren et al. (1975) observed that "although some feeding on plants does occur, it seems to be the exception rather than the rule, and it usually involves eating germ plasm of newly germinated seeds or girdling the stems of small seedlings. The damage occurs most often when a previously uncultivated area is brought under cultivation and the ants are thereby deprived of their normal food source." Glancey et al. (1979) found the red imported fire ant would damage corn seedlings under certain conditions. They also noted that the ants, under stress conditions due to flooding prior to planting, might be expected to feed on corn roots if no other food was available. Vinson (1972) observed the red imported fire ant collecting seeds of dallisgrass, *Paspalum dilatatum* Poir., but only those infested with ergot.

Wilson and Oliver (1969) and Howard (1975) concluded that foraged material indicated the fire ant was an aggressive nonspecific predator and captured what was convenient or available. However, Sterling et al. (1979) found that in a cotton ecosystem, the abundance of important predators was largely unaffected by the fire ant and concluded that it was a fairly specialized predator.

Because the fire ant is an omnivorous feeder, this report includes results of a field study conducted to determine the effect of fire ant infestations on grass yields and quality in southern Louisiana.

Methods and Materials

A study was conducted during 1977-78 at the St. Gabriel Experiment Station in a 20-hectare bermudagrass-dallisgrass pasture. The test area was divided into eight 2-hectare plots, 76.5 meters x 264 meters, each having a 0.4-hectare subplot centrally located from which data were taken. Plots were established in a completely randomized design with four replications of two treatments, mirex-treated and untreated. Treated plots received one application of mirex 4X bait at a rate of 2.24 kilograms per hectare June 7, 1977, and a second application June 4, 1978.

Fire ant activity was measured by counting active mounds (a minimum of three ants appearing on the surface of a disturbed mound) in the

0.4-hectare subplots before treatment and immediately following hay harvest at each location. Populations of arthropods, other than the fire ant, and other invertebrates in the test pasture were monitored by sweeping the vegetation with a sweep net 38.1 centimeters in diameter by making 100 horizontal 180° sweeps along a longitudinal transect in the center of each subplot. Collections were placed in plastic bags in increments of 25 sweep subsamples and were transported to the laboratory for sorting, counting, and identification. Sweep samples were taken on June 8, August 24, and September 5, 1978.

Yield samples were harvested on September 5, 1978 along a longitudinal transect through the center of each subplot after a 13-week growth period from the previous harvest. Four areas spaced equidistant along the transect were cut to a height of about 5 centimeters (Zweegers Cycle mower, P. J. Zweegers and Zonen, Geldrop, Holland) and grass from a total of 9.28 square meters (2.32 square meters from each mowed area) was collected and weighed (green weight). These samples were dried (forced air ovens) for 36 hours at 82°C and dry weights were obtained for calculation of percent moisture and dry-weight yield.

A 100-gram subsample (dry weight) was submitted to *in vitro* quality determinations. Quality measurements included those for crude protein (Kjeldahl method as described by the A.O.A.C., 1960), acid-detergent fiber (ADF), cell wall constituents (CWC), cellulose (cell), and acid-insoluble lignin (AIL) (Goering and Van Soest 1970). Hemicellulose (HC) was calculated as the difference between cell wall constituents and acid-detergent fiber. *In vitro* digestible dry matter (IVDDM) values were determined by a modified Van Soest procedure (Nelson et al. 1972).

Results and Discussion

Pre- and posttreatment mound numbers and grass yield and quality values for the mirex-treated and untreated plots are shown in Table 1. No

Table 1.—Means of the number of fire ant mounds, grass yield, and grass quality values in mirex-treated and untreated pasture plots, St. Gabriel, La., 1977-78[1]

	No. mounds/treatment		Yield		
Treatment	Pretreatment	Posttreatment	(kg. dm/ha)	% H_2O	% CWC
Treated	31.75a	14.00a	5,313.90a	67.17a	75.65a
Untreated	41.50a	38.75b	4,349.78a	68.55a	75.17a

	% Hemicellulose	**% ADF**	**% Cellulose**	**% Lignin**
Treated	38.40a	37.25a	27.40a	5.24a
Untreated	37.78a	37.40a	26.80a	5.68a

	% Ash	**% IVDDM**	**% Protein**
Treated	4.59a	48.65a	8.08a
Untreated	4.94a	48.72a	8.13a

[1] Pairs of means within a column followed by the same letter do not differ at the .05 level according to the t-test for comparison of means.

difference (P>.05) existed in yield or quality of grass produced on the mirex-treated and untreated plots in spite of about 2.75X as much ant activity in the untreated plots as indicated by mound numbers.

Invertebrates (insects primarily) collected in sweep net samples are listed in Table 2. This fauna was present in relatively low numbers and, with the exception of the reduviid and cercopid populations, did not differ significantly (P>.05) in mirex-treated and untreated areas. These arthropods, therefore, did not appear to affect grass yield or quality in the test.

Table 2.—Invertebrates other than the fire ant collected by sweep net in mirex-treated and untreated pasture plots, St. Gabriel, La. 1978[1] [2]

	Mean na./sweep	
Taxan(s)	Treated	Untreated
Acrididae/Tettiganidae	0.243a	0.196a
Gryllidae	0.284a	0.326a
Lygaeidae	0.228a	0.176a
Nabidae	0.152a	0.092a
Reduviidae	0.021a	0.049b
Pentatamidae (phytaphagaus)	0.040a	0.055a
Cicadellidae/Delphacidae	1.948a	2.097a
Cercapidae	0.063a	0.233b
Membracidae	0.017a	0.009a
Chrysamelidae (excluding flea beetles)	0.004a	0.004a
Chrysamelidae (flea beetles)	0.054a	0.040a
Caccinellidae	0.017a	0.008a

[1] Means are averages af faur replicatians an three sample dates.

[2] Means within taxons fallawed by the same letter da nat differ at the .05 level.

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Chapter II: Effect of the Red Imported Fire Ant, *Solenopsis invicta* Buren, on Soil Fertility in Mississippi River Alluvial Soil in Southern Louisiana

Abstract

Soil taken from mounds constructed by the red imported fire ant, *Solenopsis invicta* Buren, in Sharkey clay contained higher ($P<.05$) concentrations of P and K, and had lower ($P<.05$) pH than soil obtained at distances of 0.6, 1.5, and 3 meters from the mound in both ant-infested and "ant-free" areas. Concentrations of P and K, soil pH, and percent organic matter in soil taken periodically from the mound and at 0.6, 1.5, and 3 meters from mounds in areas rendered ant-free did not progressively decrease during a 1-year period nor otherwise differ from soil taken at similar sites in ant-infested areas after 1 year. Similarly, pH was stable during this period. These data indicate that ant activity does not immediately affect overall soil fertility in a given area as a result of improved soil fertility radiating away from the mound into adjacent areas, but that increase of soil nutrient content that results from fire ant mound-building activity could ultimately improve overall enrichment of the top 8 to 10 centimeters of soil surface since increased soil nutrients in mound soil do not decrease quickly after the mounds are abandoned.

Introduction

The effect of the red imported fire ant, *Solenopsis invicta* Buren, on soil fertility has been studied only slightly. In a short-term study on the influence of the imported fire ant on Louisiana pasture soil chemistry, Herzog et al. (1976) found that mounds in unimproved pastures on clay soil contained greater ($P<.05$) concentrations of phosphorus (P), that pH was increased ($P<.05$), and that organic matter was lower ($P<.05$) as compared with soil taken 1.5 meters southwest of each mound. In an improved pasture on loam soil, concentrations of both P and K were greater ($P<.05$) and pH was also higher ($P<.05$) in mound soil than in soil nearby. Gentry and Stiritz (1972) revealed that the Florida harvester ant, *Pogonomyrmex badius* (Latreille), caused accumulations of P and K at mound sites when compared with soil taken at least 5 meters from the mound. Czerinski et al. (1971) showed that in active ant mounds pH was increased and enrichment of the soil occurred with increases in organic matter, total N, available K, P, and exchangeable basic cations. In abandoned hills, the amount of these components remained at the same level. However, as the mounds dwindled the concentrations decreased and returned to the original level similar to those in nonmound soil. The changes were more distinct in muck-like soil than in alluvial soil, and the greatest changes in soil properties were associated with *Myrmica* sp. and *Lasius flavus* F.

In states such as Louisiana, where large infestations of the red imported fire ant exist, knowledge of the effect of these insects on soil fertility would be useful in rendering decisions relative to their control. The study reported here was conducted to extend that of Herzog et al. (1976) by (1) determining if the increased soil fertility found in mounds existed in a lateral gradient in soil adjacent to mounds, and (2) by gaining some indication of the long-term effect of fire ant elimination on soil fertility by measuring changes of soil fertility in adjacent test areas, one of which was infested with ants and one from which ants had been eliminated by use of mirex.

Methods and Materials

Research was conducted at the LSU Agricultural Experiment Station near St. Gabriel, La., in an established bermudagrass, *Cynodon dactylon* (L.) Pers.—dallisgrass, *Paspalum dilatatum* Poir., pasture on Sharkey clay from June 1978 until July 1979. No fertilizer or lime was applied to the test area in either of the 2 years.

The experiment was established in a completely randomized split-plot design. Two insecticide treatments, mirex-treated and untreated, served as main plot treatments for obtaining ant-infested and ant-free areas in which to measure soil fertility. Distance from mound served as subplot treatments. Twelve mature mounds (about 45 centimeters high x 60 centimeters in diameter) in each main plot that were isolated by more than 6 meters from another mound were marked with surveyors' flags as test mounds. Each of the 12 mounds served as a replication and soil was sampled from, and around, the marked mounds throughout the study. Six random core samples (15.2 x 1.9 centimeters) of soil were taken in a circular arrangement around the mound at distances of 0.6, 1.5, and 3 meters. One core was taken directly from the center of each test mound (0 distance). The top 3.1 millimeters of vegetation or vegetation residue was discarded and the six samples for each distance were combined and air dried in 0.47-liter paper cartons at room temperature for 5 to 20 days. Subsequently, they were subjected to standard chemical analysis for extractable P, K, Ca, and Mg and determinations for pH and organic matter by methods currently used in the LSU Soil Testing Laboratory. Values for K, Mg, and Ca that exceeded 500, 1,000, and 4,000 ppm, respectively, were recorded as 500+, 1,000+, and 4,000+ ppm. Data for Ca were not analyzed statistically because all samples contained concentrations above 4,000 ppm.

Soil was sampled June 15 (before being treated with mirex) and August 21, 1978, and February 19 and July 3, 1979. The area designated for main plot treatment received 4x mirex bait on June 16, 1978 at a rate of 2.24 kilograms per hectare and a second application at the same rate 4 weeks later. Data obtained were submitted to an analysis of variance. Means were tested by Duncan's multiple range test where appropriate.

Results and Discussion

Ant control in the treated area was virtually complete during the study period of about 12 months. Two small, active mounds were observed in the mirex-treated area on the last sampling date. However, these mounds were located more than 6 meters from any test mound.

Concentrations of P and K in mound soil (0 distance) were higher ($P<.05$) and pH was lower ($P<.05$) than in soil taken at any distance away from the mound (Table 1). Magnesium concentrations among distances did not differ ($P>.05$) and the percentage of organic matter differed ($P<.05$) only in soil obtained at 0.6 meter.

The higher concentration of P and K in mound soil is consistent with results obtained by Gentry and Stiritz (1972) and Czerinski et al. (1971). Although Herzog et al. (1976) found significantly higher concentrations of P in Sharkey clay mound soil, K concentration was not significantly different between mound and adjacent soil.

The uniform concentrations of Mg among distances are in agreement with results of Herzog et al. (1976). However, the results reported here are distorted because all sample measurements on the last two dates were in excess of 1,000 ppm.

The lower pH values in mounds as opposed to those in adjacent areas are contrary to previous reports. Both Herzog et al. (1976) and Czerinski et al. (1971) reported that pH was significantly higher in mound soil than in soil adjacent to the mound. However, Gentry and Stiritz (1972) found all samples to have virtually the same pH with very little variation.

Table 1.—Relative soil fertility in fire ant mounds and at three distances from mounds as indicated by overall means of five parameters of soil fertility in an improved pasture at St. Gabriel, La., 1978-79

Distance	Parameter[1]				
from mound (m)	P (ppm)	K (ppm)	Mg (ppm)	pH	% organic matter
0.0 (mound)	171.74a	465.76a	911.45a	6.39a	1.92a
0.6	89.22b	348.17b	910.04a	6.68b	2.06b
1.5	87.16b	343.58b	909.92a	6.72b	1.99a
3.0	87.21b	346.62b	911.83a	6.72b	1.98a

[1] Means within a column followed by the same letter do not differ at the .05 level according to Duncan's multiple range test.

Overall, organic matter content did not differ ($P<.05$) in ant-infested and ant-free areas. The higher level of organic matter ($P<.05$) found at 0.6 meter from the mound cannot be explained. However, these data agree with those of Herzog et al. (1976) in that no differences existed in the percentage of organic matter in soil taken at 1.5 meters from the mound and in mound soil.

Overall means that reflect changes in the five parameters measuring soil fertility in soil from ant-infested (untreated) vs. ant-free (mirex-treated) areas over a 1-year period are shown in Table 2. The higher P content ($P<.05$) in soil from the untreated area could not be attributed to the presence or absence of the ants since comparison of overall means in ant-free and ant-infested areas (Figure 1) showed that a higher ($P<.05$) level of P existed in the untreated area before treatment than in the area designated for mirex treatment. This difference remained approximately the same throughout the study period and was confirmed by analysis of variance, which showed no treatment X date interaction ($P>.05$) for P content. This indicated that changes in P levels of soil, during the 12 months of study, were not significantly different ($P>.05$) between the two treatments, but that the original pretreatment difference continued to exist. For K, however, a significant ($P<.05$) treatment X date interaction did occur in soil from the nontreated area even though pretreatment means indicated that the nontreated area had higher levels of K (Figure 2). This interaction was caused primarily by the greater increase of K in soil from the treated area, which occurred between the pretreatment sample date (June 15, 1978) and the second sample date (Sept. 21, 1978). No explanation can be offered for this unusual increase in relation to changes that occurred during the remainder of the year. In spite of the results being distorted by some mound measurements exceeding 500 ppm, K concentrations fluctuated seasonally in both ant-free and ant-infested areas, with the magnitude of fluctuation greater in ant-free than in ant-infested areas. However, these fluctuations were so variable that after a year of study, differences between treated and untreated soils were essentially the same as in pretreatment analyses.

Table 2.—Relative soil fertility in adjacent improved pastures, one fire ant-free for 1 year and one naturally infested, as indicated by overall means of five parameters of soil fertility, St. Gabriel, La., 1978-79

	Parameter[1]				
Treatment	P (ppm)	K (ppm)	Mg (ppm)	pH	% organic matter
Ant-free	94.13a	365.11a	918.78a	6.62a	1.96a
Ant-infested	123.48b	386.75b	902.75b	6.63a	2.01a

[1] Means within a column followed by the same letter do not differ at the .05 level.

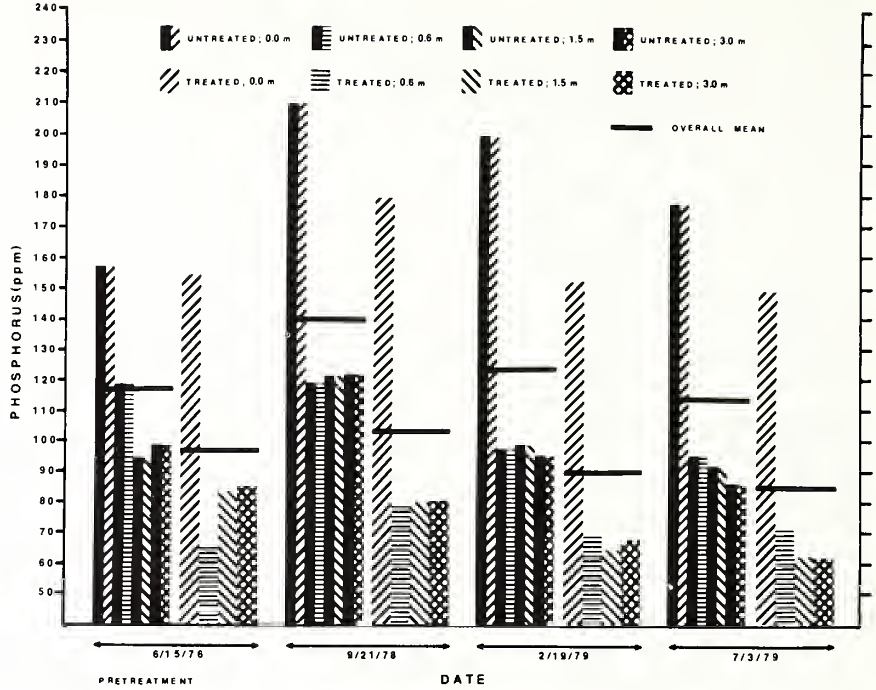

Fig. 1.—Concentrations of P (means of 12 mound sites) in soil taken from fire ant mounds and at distances of 0.6, 1.5, and 3 meters from the mounds in ant-free (mirex-treated) and ant-infested (untreated) areas of an improved pasture, St. Gabriel, La., 1978-79.

Mg concentration was greater (P<.05) in ant-free plots (Table 2). However, the overall difference was caused by a higher concentration of Mg in the ant-free area in pretreatment soil analysis (Figure 3). The significant (P<.05) treatment X date interaction was caused by samples obtained Feb. 19 and July 3, 1979, in which all measurements exceeded 1,000 ppm, thus biasing the statistical analysis. Since measurements taken only on Sept. 21, 1978, were random, valid conclusions regarding treatments and their effect on Mg concentrations could not be made from these data.

Values for pH in soil from the ant-free and ant-infested areas were not significantly (P>.05) different (Table 2). The treatment X date interaction was significant (P<.05). However, a greater pretreatment difference between the two treatments than differences on the three posttreatment sampling dates (Figure 4) indicated that pH did not differ between the two treatments over time.

Percent organic matter was not significantly different (P>.05) in the ant-free and ant-infested areas (Table 2). The pretreatment (June 15, 1978)

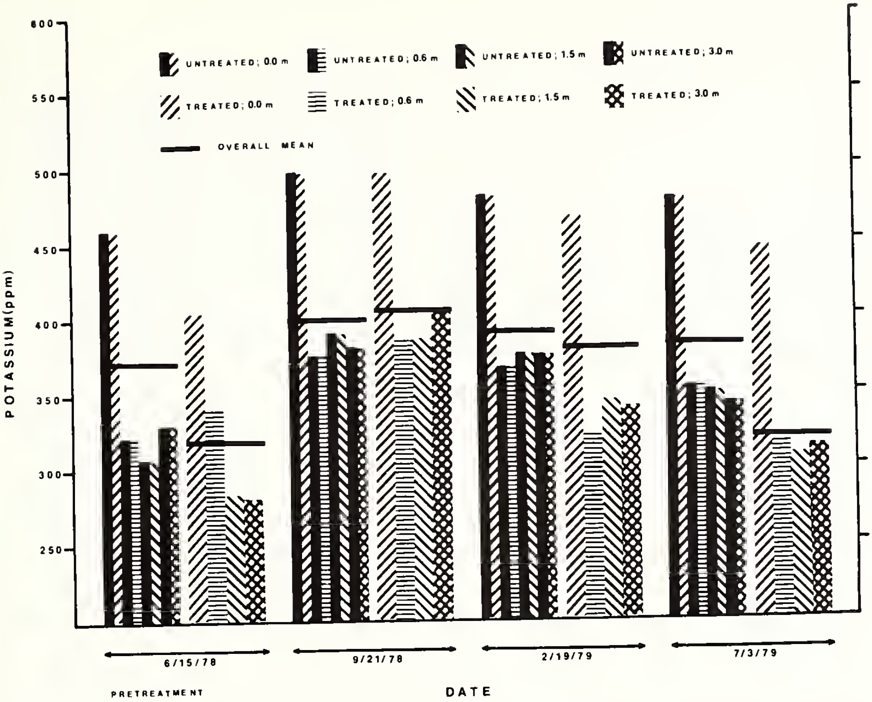

Fig. 2.—Concentrations of K (means of 12 mound sites) in soil taken from fire ant mounds and at distances of 0.6, 1.5, and 3 meters from the mounds in ant-free (mirex-treated) and ant-infested (untreated) areas of an improved pasture, St. Gabriel, La., 1978-79.

and the first posttreatment (Sept. 21, 1978) samples showed a higher percentage of organic matter content in the area designated to be ant-free (Figure 5). However, a small fluctuating difference between organic matter in the treatments caused a significant ($P<.05$) overall treatment X date interaction that does not appear to be related to fire ant activity because of the pretreatment differences. Rather, these data indicate that changes in organic matter content of soil during a 1-year period were normal seasonal changes and were essentially the same regardless of the presence or absence of the ants.

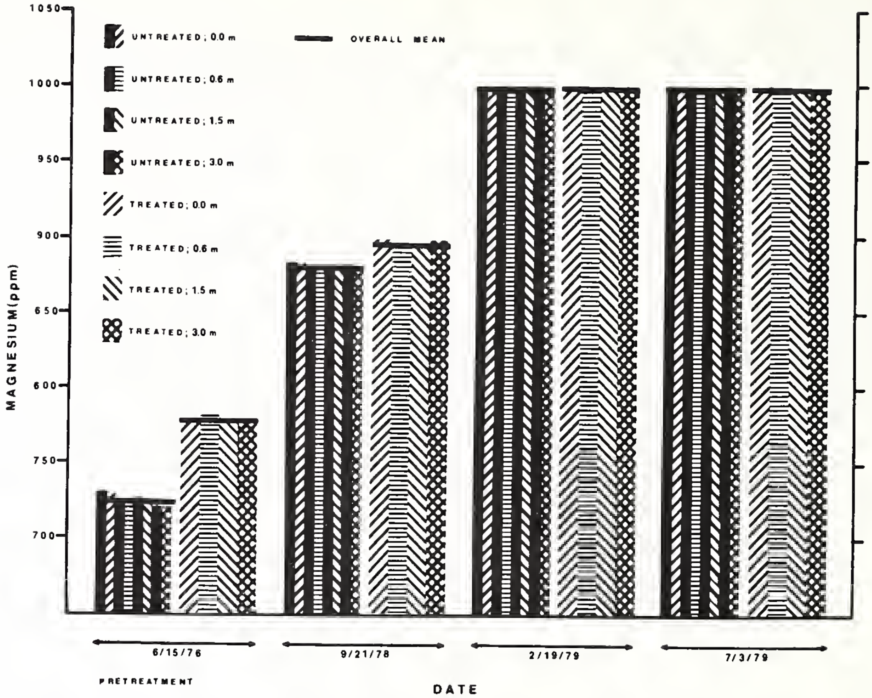

Fig. 3.—Concentrations of Mg (means of 12 mound sites) in soil taken from fire ant mounds and at distances of 0.6, 1.5, and 3 meters from the mounds in ant-free (Mirex-treated) and ant-infested (untreated) areas of an improved pasture, St. Gabriel, La., 1978-79.

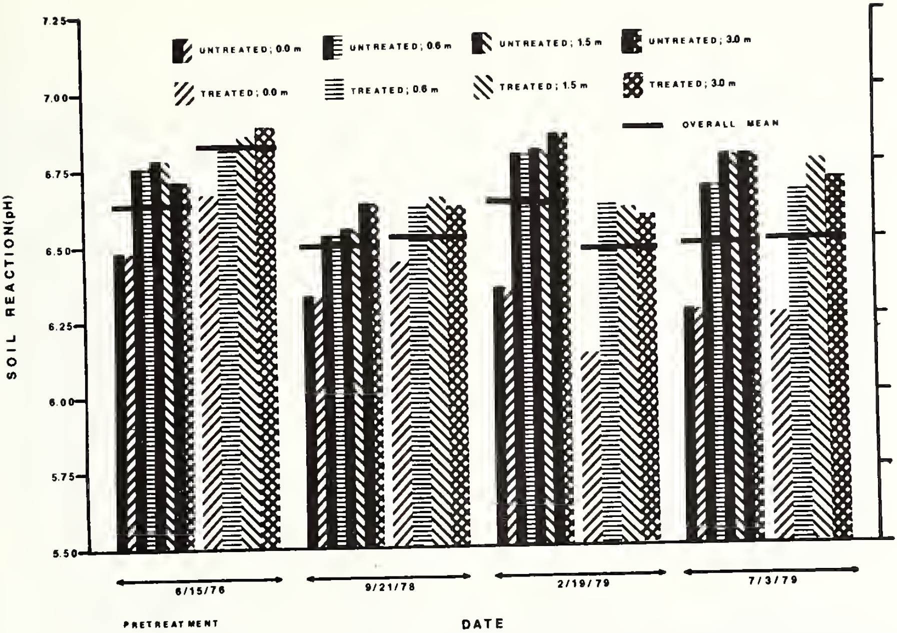

Fig. 4.—Soil pH in fire ant mounds and at distances of 0.6, 1.5, and 3 meters from the mounds in ant-free (mirex-treated) and ant-infested (untreated) areas of an improved pasture, St. Gabriel, La., 1978-79.

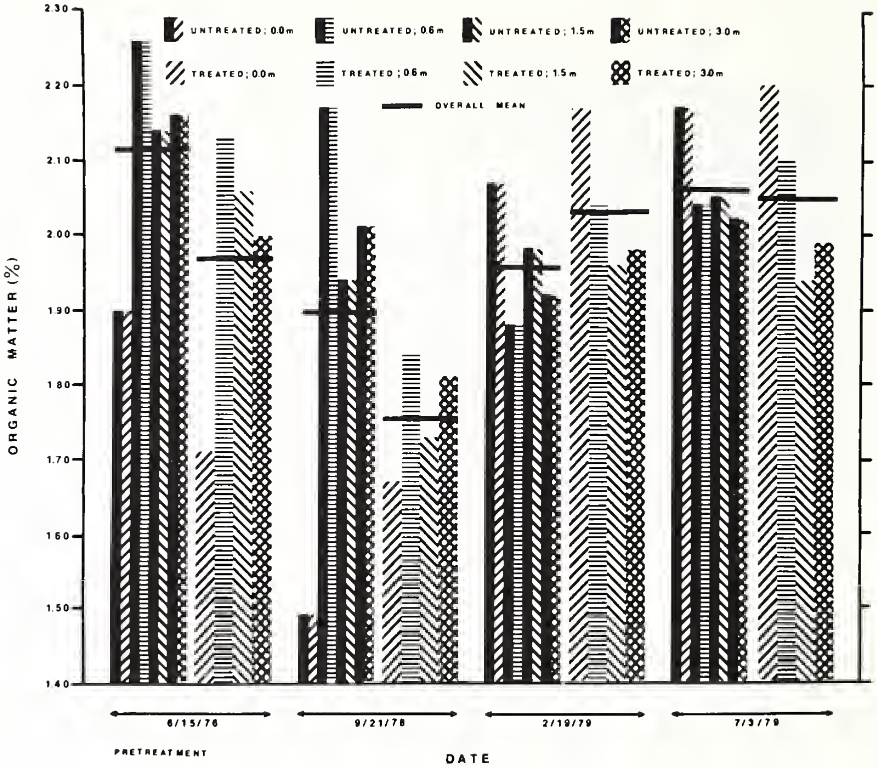

Fig. 5.—Mean percent organic matter of soil in fire ant mounds (means of 12 mound sites) and at distances of 0.6, 1.5, and 3 meters from the mounds in ant-free (mirex-treated) and ant-infested (untreated) areas of an improved pasture, St. Gabriel, La., 1978-79.

Conclusions

The data presented here support those of Herzog et al. (1976) that showed red imported fire ant activity does modify soil fertility in mound soil by increasing concentrations of P and K, but differ by showing a reduced soil pH. This extension of their work showed that at any given time the increased fertility resulting from ant activity is limited to the mound and thus contributes relatively little to the overall fertility level of a given area. In this study, the number of ant mounds per hectare was 90.4 averaging 0.24 square meter in area, which covered a total of only 21.7 square meters per hectare, or 0.22 percent. However, if the decrease of P and K in mound soil occurs slowly, as was indicated by no decrease of P and K in ant-free mounds after 1 year in this study, an overall enrichment of the top 8 to 10 centimeters of soil ultimately could occur as a result of the mound-building activity.

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Chapter III: Effect of Mound Disruption During Winter and Other Seasons on Red Imported Fire Ant, *Solenopsis invicta* Buren, Mound Number and Size in Pastures in Southern Louisiana

Abstract

Results of a study at St. Gabriel, La., from 1977 into 1979 indicated that mound dragging in winter immediately before temperature decreases to below 0°C reduced ($P<.05$) red imported fire ant, *Solenopsis invicta* Buren, mound numbers (about 50 percent) during the subsequent crop-growing season. Four "dragging" regimes conducted through fall, spring, and summer did not significantly ($P>.05$) reduce mound numbers.

All but one "drag" regime, regardless of the season or seasons in which they were conducted, produced a significant ($P<.05$), but inconsistent, reduction in ant mound size.

Introduction

Study of the effectiveness of cultural controls such as mound disruption for control of the red imported fire ant, *Solenopsis invicta* Buren, has been virtually nonexistent. One report (Green 1962) showed that numbers of active fire ant mounds per acre were significantly increased when mounds were disturbed in the spring by mechanical dragging. Because of a lack of information on nonchemical controls for the red imported fire ant, population suppression of this insect has been dependent on chemicals. The ban on use of mirex, the only labeled insecticide for fire ant control in pastures at that time, prompted this study to determine (1) the efficiency of mound destruction by various regimes of dragging in warm and cool seasons of the year for suppressing fire ant populations, and (2) drag regime effect on mound size in southern Louisiana.

Methods and Materials

Two separate experiments, warm season (summer) and cool season (winter) mound disruption, were conducted at the St. Gabriel Agricultural Experiment Station from November 1977 until April 1979. Destruction of mounds was accomplished by dragging the appropriate ant-infested areas with a steel "I"-beam drag (4.6 meters in length and about 909 kilograms) pulled with a tractor. Fire ant activity was measured by counting active mounds (at least three ants appearing on a disturbed mound) in a 91.4- x 6.1-meter diagonal transect centrally located through each plot. The number of mounds per plot was averaged and used as an index for comparison. Diameter and height of 10 randomly selected, active mounds in each plot were measured to the nearest 2.5 centimeters and means were calculated for comparative purposes.

Permanent pastures of mixed bermudagrass, *Cynodon dactylon* (L.) Pers., and dallisgress, *Paspalum dilatatum* Poir., overseeded with annual ryegrass, *Lolium multiflorum* Lam., in the fall were used as experimental areas. They were routinely subjected to rotational grazing and fertilized and limed according to soil analysis. Five 2-hectare test plots were established in three 20-hectare pastures with each plot located a minimum of 30.4 meters from adjacent plots. Subsequently, five treatments (drag regimes) were placed on the plots in a randomized block design (RBD, three replications) and were compared throughout the fall, spring, and summer. Drag regimes consisted of (1) two drags per year—one fall, one spring; (2) three drags per year—simulated hay harvest schedule; (3) four drags per year—one fall, three late spring through early summer; (4) five drags per year—evenly spaced through spring, summer, and fall, and (5) 0 drags per year—control. Pretreatment mound counts were taken Nov. 22, 1977. Posttreatment mound counts and mound measurements were made April 4, May 16, June 22, July 28, Sept. 7, and Nov. 9, 1978, and April 30, 1979.

An improved pasture containing several species of grasses and broadleaf weeds, routinely clipped once per year and lightly grazed, served as the experimental area for winter treatments. Treatments, consisting of (1) one drag per winter, (2) two drags per winter, and (3) 0 drags per winter (control), were placed in a RBD in 1-hectare plots separated by ditches about 0.5 meter deep and 1.5 meters wide. Dragging was scheduled so air temperature fell below 0°C the night following each drag. Pretreatment mound counts were taken Feb. 4, 1978. Posttreatment mound counts and mound measurements were made March 30, May 18, June 23, July 31, Sept. 14, and Nov. 9, 1978, and May 2, 1979.

Results

Dragging mounds three, four, and five times per year during the warm season did not reduce mound numbers ($P > .05$) at any time during the study (Table 1). The increased ($P < .05$) number of mounds on the last two sample dates in the two-drags-per-year treatments occurred about 7 months after the final drag, and apparently was not a result of the dragging.

Overall means for mound height indicated that all summer drag regimes reduced mound height ($P < .05$) with two, three, and five drags per year being more effective than four per year (Table 2). However, comparison of

Table 1.—Effect of four warm-season regimes of mound dragging on fire ant population as indicated by mound numbers, St. Gabriel, La., 1977-79

Treatment (drag regime)	Mean no. mounds/plot (pretreatment)	Sample date						
		4/4/78	5/16/78	6/22/78	7/28/78	9/7/78	11/9/78	4/30/79
		% of posttreatment to pretreatment mound numbers and no. of drags[1]						
1	10.0	82.8(1)[2]	38.3(2)	34.9(2)	6.1(2)	36.2(2)	133.1*(2)	207.4**(2)
2	12.0	62.1(0)	41.8(0)	28.6(1)	8.6(2)	35.6(2)	79.9 (3)	94.2 (3)
3	14.7	58.9(1)	49.9(2)	32.6(3)	22.8(4)	50.8(4)	100.9 (4)	115.0 (4)
4	12.6	63.9(1)	39.6(2)	18.5(3)	12.6(3)	22.8(3)	44.9 (4)	56.0 (5)
5	16.3	55.4	39.2	36.4	11.8	27.9	68.7	84.9

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[1] For comparison of individual treatment values with the control value on individual sample dates, $P<.05$ = *, $P<.01$ = **.

[2] Numbers in parentheses = number of drags prior to sample date.

Table 2.—Overall effect of four warm-season regimes of mound dragging on fire ant mound height and diameter, St. Gabriel, La., 1977-79

Treatment (drag regime)	Mean mound height	Mean mound diameter
	(cm)	(cm)
1	9.4a[1]	36.6a
2	9.4a	40.1bc
3	10.4b	38.1ab
4	8.9a	39.3ab
5	11.7c	42.7c

[1] Means within a column followed by the same letter do not differ at the .05 level according to Duncan's multiple range test.

mound height in the undragged control plots with each drag treatment on each sample date showed mound height reduction to be inconsistent within drag regimes (Table 3). This inconsistency of height within treatments appeared to be related, in part, to (1) the time interval between actual dragging and data collection, since in some drag regimes height measurement on the sample data would be closer to a drag date than in others, and (2) weather conditions, since a more rapid rate of mound growth was associated with rainy periods.

Warm-season increase of mound height progressed at a relatively rapid rate after dragging. In June and July, differences ($P<.05$) in mound height occurred only at 6 and 8 days posttreatment, respectively (Table 3). No difference ($P>.05$) was detected in June at 27 days nor in July at 42 days posttreatment. However, height of the dragged mounds tended to be less than that of those in the control. No consistent differences were detected between dragged and undragged mound diameters following warm season treatment (Table 4), although overall mound diameters were reduced ($P<.05$) by all but the simulated hay harvest (Treatment 2) drag regime (Table 2).

Both winter-treatment regimes tested resulted in a substantial (about 50 percent) reduction ($P<.05$) of mound numbers the following summer (Table 5). Further reductions in late summer and early fall apparently were associated with droughty weather. An increase in active mound numbers occurred in late fall but was lower (25 to 50 percent) than predrag numbers ($P<.05$) at the beginning of the second spring postdrag. Substantial differences ($P<.05$) existed between heights of dragged and nondragged mounds throughout the summer following winter drags (Table 6). Dragged mounds were about 50 percent as tall as nondragged mounds 7 months postdrag and were about 75 percent as tall after 11 months. Mounds subjected to winter treatment were also considerably smaller ($P<.01$) in diameter than nondragged mounds throughout the year following treatment (Table 7).

Table 3.—Effect of four warm-season regimes of dragging on fire ant mound height, St. Gabriel, La., 1978-79

Treatment (drag regime)	Sample date						
	4/4/78	5/16/78	6/22/78	7/28/78	9/7/78	11/9/78	4/30/79
	Mean mound height[1] (cm) and no. days from last drag						
1	7.6**(117)[2]	7.1**(25)	3.8 (63)	11.4 (98)	14.2**(139)	8.3**(202)	10.9**(374)
2	8.3*	9.9	3.3 (27)	4.8**(8)	13.7**(49)	9.1* (59)	10.9**(231)
3	7.4**(117)	9.4 (25)	2.8*(6)	11.2 (42)	18.0 (83)	9.7 (146)	12.9 (318)
4	9.4 (117)	9.4 (25)	3.6 (27)	11.7 (63)	15.5 (104)	5.1**(31)	8.6**(160)
5	11.4	10.1	5.3	12.4	17.3	11.4	14.2

[1] Average of three replications, 10 mounds per replication; for comparison of individual treatment values with the control value on individual sample dates, P<.05 = *, P<.01 = **.

[2] Numbers in parentheses = number of days from last drag.

Table 4.—Effect of four warm-season regimes of dragging on fire ant mound diameter, St. Gabriel, La., 1978-79

Treatment (drag regime)	Sample date						
	4/4/78	5/16/78	6/22/78	7/28/78	9/7/78	11/9/78	4/30/79
	Mean mound diameter[1] (cm) and no. days from last drag						
1	52.8(117)[2]	34.8*(25)	40.6(63)	30.2 (98)	34.5(139)	29.9**(202)	34.5**(374)
2	53.1	45.7	47.2(27)	30.9 (8)	30.9(49)	35.0 (59)	38.4**(321)
3	46.2(117)	37.8 (25)	43.7(6)	26.4*(42)	37.1(83)	33.5 (146)	41.9 (318)
4	59.9(117)	40.1 (25)	44.9(27)	28.7 (63)	33.3(104)	33.0 (31)	35.8**(160)
5	52.3	44.7	44.1	33.8	37.8	40.1	48.5

[1] Average of three replications, 10 mounds per replication; for comparison of individual treatment values with the control value on individual sample dates, P<.05 = *, P<.01 = **.

[2] Numbers in parentheses = number of days from last drag.

Table 5.—Effect of two regimes of winter mound dragging on fire ant population as indicated by mound numbers, St. Gabriel, La., 1978-79

Treatment (drag regime)	Mean no. mounds/plot pretreatment (2/14/78)	Sample date						
		3/30/78	5/18/78	6/23/78	7/31/78	9/14/78	11/9/78	5/2/79
		% of posttreatment to pretreatment mound numbers and no. of drags[1]						
1	15.5	103.5 (1)[2]	57.5**(1)	46.6**(1)	23.5* (1)	33.0**(1)	65.5(1)	54.8**(1)
2	12.3	94.4*(2)	50.1**(1)	48.8**(2)	3.6**(2)	49.2**(2)	72.5(2)	72.7* (2)
3	12.5	136.5	125.8	103.4	66.0	114.7	92.2	109.9

[1] For comparison of individual treatment values with the control value on individual sample dates, $P<.05 = *$, $P<.01 = **$.

[2] Numbers in parentheses = number of drags prior to sample date.

Table 6.—Effect of two regimes of winter mound dragging on fire ant mound height, St. Gabriel, La., 1978-79

Treatment (drag regime)	Sample date						
	3/30/78	5/18/78	6/23/78	7/31/78	9/14/78	11/9/78	5/2/79
	Mean mound height[1] (cm) and no. days from last drag						
1	3.8**(44)[2]	12.2**(93)	12.4**(129)	14.7**(167)	20.8**(211)	17.2**(267)	17.5* (441)
2	3.3**(30)	12.9**(79)	12.2**(115)	14.5**(153)	17.5**(197)	16.2**(253)	14.9**(427)
3	22.8	21.3	21.8	31.2	25.7	20.3	22.6

[1] Average of 10 mounds; for comparison of individual treatment values with the control value on individual sample dates, $P<.05 =*$, $P<.01 =**$.

[2] Numbers in parentheses = number of days from last drag.

Table 7.—Effect of two regimes of winter mound dragging on fire ant mound diameter, St. Gabriel, La., 1978-79

Treatment (drag regime)	Sample date						
	3/30/78	5/18/78	6/23/78	7/31/78	9/14/78	11/9/78	5/2/79
	Mean mound height[1] (cm) and no. days from last drag						
1	49.0**(44)[2]	38.8**(93)	34.5**(129)	36.3**(167)	41.9**(211)	47.8**(267)	58.9* (441)
2	44.1**(30)	47.9**(79)	33.5**(115)	29.5**(153)	39.4**(197)	40.3**(253)	46.7**(427)
3	68.6	63.0	61.9	56.8	66.3	66.3	68.3

[1] Average of 10 mounds; for comparison of individual treatment values with the control value on individual sample dates, P<.05 = *, P<.01 = **.

[2] Numbers in parentheses = number of days from last drag.

Discussion

Disruption of fire ant mounds by knocking them down with a 909-kilogram drag resulted in reduced populations of ants as indicated by the number of active colonies, if treatment was conducted during winter immediately before air temperature decreased below 0°C. Warm weather dragging appeared to be ineffective in suppressing ant populations. However, dragging periodically throughout or at any time during the year (especially in cold weather) significantly reduced overall mound height, but only for a relatively short time from a practical agricultural standpoint. Data on mound heights and diameters in this study (apparently related to wet and dry periods of weather) were inconsistent. Therefore, none of the drag regimes tested appeared to adequately serve as a guide for recommending specific time intervals of mound disruption to obtain minimum heights and diameters at any given time. Winter dragging, however, does offer promise as a management tool for suppressing populations as well as reducing mound height and diameter with a minimum of effort, expense, and adverse environmental effects characteristic of some chemical treatments.

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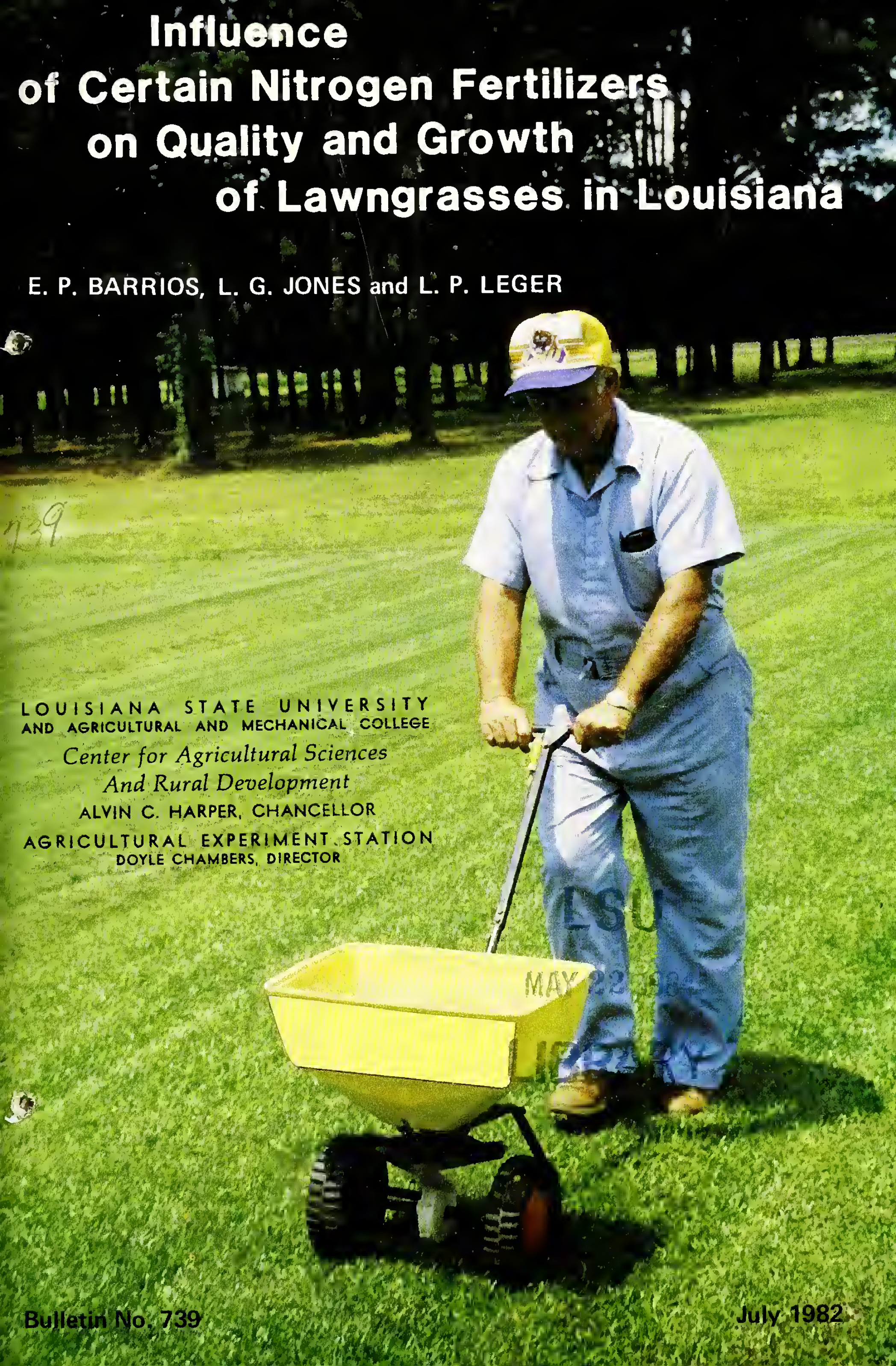

Influence of Certain Nitrogen Fertilizers on Quality and Growth of Lawngrasses in Louisiana

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Influence of Certain Nitrogen Fertilizers On Quality and Growth of Lawngrasses in Louisiana

E. P. BARRIOS, L. G. JONES AND L. P. LEGER[1]

Many grass species are used as lawngrasses in Louisiana due to variations in climate, soil, native stands, and individual preferences. Numerous trees limit shade-intolerant bermudagrasses to sunny areas, and high maintenance requirements further restrict their usage on lawns. Zoysiagrasses are also generally planted only where equipment and personnel are available to manage them properly. Presently, St. Augustine, centipede, and Floratam are the principal lawngrasses in Louisiana, with smaller amounts of carpetgrass located in areas where soil elevations are lower and more moisture is present.

Estimates indicate that about 80 percent of Louisiana lawns are planted with St. Augustine, followed by centipede and Floratam turfgrasses. The widespread prevalence of St. Augustine decline (SAD) virus in southern Louisiana has resulted in most lawns being established since 1975 with centipede or Floratam. No newly released St. Augustine varieties tested here have shown levels of resistance to the SAD virus that are sufficient to justify that they replace those presently used. However, this species could continue to represent the largest lawngrass acreage in Louisiana for some time, depending on the virulence and spread of the disease and the varietal resistance that may be developed by turfgrass breeders.

Turfgrasses require more nitrogen (N) than any of the other essential elements supplied by soils and fertilizers, normally containing from 2 to 6 percent N in dried foliar samples (*10, 15, 25*[2]). Nitrogen has a great influence on the growth rate of turfgrass, which usually increases with the application of larger amounts of this element to certain levels (*5, 24*). The color and density of turf are generally improved by the addition of the proper amount of N (*12, 21*). However, excessive N fertilization of turfgrasses promotes thatching and susceptibility to some diseases (*9, 11*). Nitrogen deficiency may cause reduced cold hardiness of lawngrasses, but excesses of this element are especially responsible for winter damage to turf (*4, 17*).

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[2] Italic numbers in parentheses refer to Literature Cited, page 20.

Nitrogen fertilizer sources for lawngrass use are numerous, ranging from very soluble forms, such as ammonium nitrate and urea, to slow-release types, including principally ureaformaldehyde (UF), isobutylidene diurea (IBDU), and sulfur-coated urea (SCU). Most dry fertilizers for lawns presently contain UF as a source of N, but many lawn-care companies use UF and/or urea in a liquid form that is sprayed on the grass. Some N sources are combined in a mixed fertilizer, usually also containing phosphorus (P) and potassium (K), such as 8-8-8 or 12-12-12. All three of these elements are necessary in certain critical amounts for production of a high-quality lawn (*8*). However, in areas of high rainfall and temperature, such as Louisiana, maintenance of an adequate supply of N is difficult since these environmental factors cause the rapid loss of this element from the soil following application.

Studies were conducted at the Burden Research Center in Baton Rouge during 1978 and 1979 to determine the influence of several N sources, rates, and application frequencies on the quality and growth of the three lawngrasses most grown in Louisiana. The soil type at this location (Mississippi River Terrace) represents from 10 to 15 percent of that on which lawns are planted in Louisiana. The results presented here, therefore, would be valid only for this soil or closely similar soils, and might not apply to grass species and N sources other than those used in this research.

Materials and Methods

The experimental design was a randomized block with three replications of 18 N treatments and three lawngrasses (centipede, Floratam, and St. Augustine). Nitrogen sources used were UF, IBDU, and liquid urea (LU), applied at three rates and two frequencies in 1978 and 1979 from April to October (Table 1).

Plots of 3 feet by 6 feet each were planted by solid sodding in the spring of 1977 so that all grasses were at a comparable stage of maturity in April of 1978 when the initial N treatments were applied. A preplant starter fertilizer, consisting of 1 pound of N (ammonium nitrate) and 5 pounds each of P_2O_5 (treble superphosphate) and K_2O (potassium chloride) per 1,000 square feet, was incorporated into the soil to a depth of 4 inches prior to sodding. During the summer of 1977, the turf was maintained by applying 1 pound of N (ammonium nitrate) and 5 pounds each of P_2O_5 and K_2O per 1,000 square feet in July. The soil at this location was a silt loam of the Calhoun series, with a pH varying from 5.7 to 6.4 among plots. In February of 1979 the pH range was unchanged, with extractable P[3] and K[4] ranging

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[3] Extracted with 0.1 N HCl + 0.03 N NH_4F at a ratio of 1 part medium to 20 parts extractant.

[4] Extracted with 1.0 N NH_4OAc buffered at pH 7.0 at a ratio of 1 part medium to 10 parts extractant.

Table 1.—Nitrogen fertilizer treatments, 1978 and 1979

Treatment no.	Treatment[1]	N rate per application[2]	Total N per year[3]
1	UF — monthly	0.5	3.0
2	IBDU — monthly	0.5	3.0
3	LU — monthly	0.5	3.0
4	UF — bimonthly	1.0	3.0
5	IBDU — bimonthly	1.0	3.0
6	LU — bimonthly	1.0	3.0
7	UF — monthly	1.0	6.0
8	IBDU — monthly	1.0	6.0
9	LU — monthly	1.0	6.0
10	UF — bimonthly	2.0	6.0
11	IBDU — bimonthly	2.0	6.0
12	LU — bimonthly	2.0	6.0
13	UF — monthly	1.5	9.0
14	IBDU — monthly	1.5	9.0
15	LU — monthly	1.5	9.0
16	UF — bimonthly	3.0	9.0
17	IBDU — bimonthly	3.0	9.0
18	LU — bimonthly	3.0	9.0

[1] Source and application frequency (UF = ureoformaldehyde; IBDU = isobutylidene diurea; LU = liquid urea).

[2] Lbs. per 1,000 ft^2 per application.

[3] Lbs. per 1,000 ft^2, April to October (applied April 3, May 3, June 2, July 3, August 3, and September 7).

among plots from 72 to 225 ppm and 54 to 168 ppm, respectively. Calcium (Ca) and magnesium (Mg) levels varied among plots from 990 to 1,750 ppm and 209 to 281 ppm, respectively, with copper (Cu) and zinc (Zn) varying from 1 to 6 ppm, iron (Fe) from 49 to 188 ppm, and organic matter from 1.2 to 3.2 percent (*6*).

Soil levels of extractable nutrients other than N were monitored periodically during 1978 and 1979, with P and K applied (from treble superphosphate and potassium chloride) when soil analyses indicated they were necessary. During the 1978 growing season, P varied among plots from 24 to 306 ppm, K from 17 to 206 ppm, Ca from 670 to 1,600 ppm, Mg from 114 to 319 ppm, and pH from 5.4 to 6.9. On the last sampling date (August), Cu ranged from 1 to 3 ppm, Fe from 20 to 68 ppm, Zn from 1 to 2 ppm, and organic matter from 0.7 to 2.4 percent.

The soil analyses from June to October of 1979 showed the following extractable nutrient levels: P varied among plots from 17 to 265 ppm and K from 14 to 168 ppm, both being highest at the end of the season. Ca and Mg were still variable, ranging from 646 to 2,057 ppm and 113 to 351 ppm, respectively, while the pH was from 5.5 to 7.0, but generally lower than in 1978. Soil organic matter increased slightly, varying from 0.6 to 3.7 percent.

The final soil sample was obtained in April of 1980, showing that extractable nutrient level ranges among plots were: P, from 10 to 230 ppm; K, from 26 to 150 ppm; Ca, from 678 to 1,642 ppm, and Mg, from 117 to 290 ppm. Soil pH varied from 5.4 to 7.0, and organic matter content was from 1.1 to 2.8 percent, increasing somewhat over that of 1979.

Extractable P, K, Ca, Mg, and pH and organic matter levels were somewhat variable in the area used for this research. It was recognized that this was an undesirable situation; however, since it was the only available space with this soil type and there was a pressing need for home lawn turfgrass fertility data, the plots were located at that site.

The turfgrasses were mowed weekly at a height of 2.5 inches, with a 26-inch wide reel-type mower equipped with a basket to remove clippings. The same mower was used to obtain yield samples. Plots were dethatched once each year during the same week of July. Standard insect and disease control measures were practiced (no SAD virus was indicated in the St. Augustine plots during 1978 or 1979). Although rainfall fluctuated considerably, at least 1 inch of moisture per week was maintained by supplemental irrigation when necessary.

Experimental data were obtained monthly (April to October) of each year. Yields of clippings were collected from grass that was not wet with dew or rain, unmowed for the previous 7 days. The same clippings were also used for foliar analyses for N, P, K, Mg, Cu, Fe, and Zn content *(22)*. Foliar samples were dried at 95°F (35°C) for 48 hours and ground in a stainless steel Wiley mill prior to analysis. Turf quality was evaluated visually by a panel of five faculty members within 48 hours after yield data were obtained. The panel was composed of the same members throughout the experiment, with ratings based on a visual scale of 1 (poorest) to 9 (best) in appearance and density in 1978 and 1979. The 1980 evaluation was changed (0 = dead, 8 = best) because of cold damage to the turfgrasses, especially at higher N rates, during the winters of 1978-1979 and 1979-1980 (Tables 2 and 3). A rating of less than 4.5 was not considered as acceptable quality lawngrass during any of the 3 years. Six sets of yield records and quality evaluations were made in each of the 1978 and 1979 growing seasons.

Results and Discussion

Grass quality and yield apparently were not associated with one another (Tables 2, 3, and 4). On the average, treatment (N source, rate or frequency) had no significant influence on quality (means of three grasses and 2 years). These data are dissimilar to those obtained here in N research with Tifgreen bermudagrass on golf greens, using generally higher rates but with two of the same sources of the element *(1)*. Shoot density has been proposed as a better measurement of golf green turfgrass quality than

Table 2.—Effect of treatment on quality and yield of three lawngrasses (means of 12 harvest dates and evaluations in 1978 and 1979 and one evaluation in 1980)

Treatment	1978 and 1979						Means, 3 grasses, 1978 and 1979		Means, 3 grasses, 1980
	Centipede		Floratam		St. Augustine				
no.	Quality[1]	Yield[2] [3]	Quality[1]	Yield[2] [3]	Quality[1]	Yield[2] [3]	Quality[1]	Yield[2] [3]	Quality[4]
1	6.3a[5]	121	5.1b	102	4.9b	94	5.4	105	1.9
2	6.2a	112	5.0b	110	3.9c	121	5.0	114	1.2
3	6.3a	139	5.1b	124	4.8b	97	5.4	120	1.9
4	6.2a	120	4.7b	92	4.6b	122	5.2	111	1.4
5	6.1a	118	5.0b	80	4.8b	96	5.4	98	1.5
6	6.4a	157	5.2b	122	4.9b	109	5.5	129	1.4
7	6.1a	116	5.2b	135	4.7b	112	5.4	121	1.7
8	6.6a	157	5.3b	143	3.9c	132	5.3	144	0.7
9	6.5a	192	5.5b	186	4.6b	143	5.5	177	1.4
10	6.2a	156	5.3b	145	4.7b	125	5.4	142	0.9
11	6.2a	178	5.2b	156	3.9c	141	5.1	158	0.6
12	6.5a	185	5.5b	169	4.2bc	136	5.3	164	1.5
13	6.7a	188	5.4b	156	4.3bc	134	5.4	160	1.0
14	6.6a	208	5.4b	202	3.9c	128	5.3	179	0.6
15	6.7a	231	5.4b	208	5.1b	177	5.8	205	1.4
16	6.2a	178	5.4b	175	4.5bc	141	5.4	164	1.1
17	6.6a	183	5.7b	186	4.3bc	140	5.5	168	0.9
18	6.7a	248	5.4b	192	4.4bc	153	5.6	201	0.8

[1] 1-9, 9 = best.

[2] Grams fresh weight/plot 13 ft^2 (7 days growth, 2½-inch height of cut).

[3] No significant differences.

[4] Evaluated June 19; 0 = dead, 8 = best.

[5] Means with at least one letter in common are not significantly different at the 5% level of probability according to Duncan's Multiple Range Test.

Table 3.—Influence of treatment and year on quality of three lawngrasses (means of 12 evaluations in 1978 and 1979 and one evaluation in 1980)

Treatment	St. Augustine			Floratam			Centipede			Yearly means (3 grasses)		
no.	1978[1]	1979[1]	1980[2]	1978[1]	1979[1]	1980[2]	1978[1]	1979[1]	1980[2]	1978[1]	1979[1]	1980[2]
1	5.7	4.1	2.3	5.3	4.7	1.4	6.5	6.0	2.0	5.8	4.9	1.9
2	5.0	2.8	1.0	5.5	4.6	1.0	6.4	6.1	1.5	5.6	4.5	1.2
3	5.7	3.9	2.1	5.5	4.7	1.3	6.3	6.3	2.4	5.8	5.0	1.9
4	5.7	3.7	1.0	5.1	4.3	1.0	6.2	6.1	2.1	5.6	4.7	1.4
5	5.9	3.8	1.8	5.6	4.4	0.6	6.3	5.9	2.1	5.9	4.7	1.5
6	5.9	3.9	1.0	5.6	4.7	1.1	6.6	6.1	2.0	6.0	4.9	1.4
7	5.4	3.9	1.0	5.4	4.9	2.0	6.0	6.1	2.0	5.7	5.0	1.7
8	5.1	2.8	0.6	5.8	4.8	0.6	6.5	6.6	0.9	5.8	4.7	0.7
9	6.0	3.2	1.3	5.9	4.9	1.6	6.5	6.3	1.2	6.1	4.8	1.4
10	5.5	3.8	1.0	5.5	5.1	1.0	6.2	6.3	0.7	5.7	5.1	0.9
11	5.2	2.4	0.3	5.7	4.6	0.7	6.1	6.3	0.7	5.7	4.4	0.6
12	5.7	2.6	1.4	6.0	4.9	1.0	6.5	6.4	2.0	6.0	4.6	1.5
13	5.1	3.5	0.7	5.5	5.3	1.1	6.6	6.6	1.2	5.7	5.1	1.0
14	5.6	2.2	0.5	5.6	5.1	1.0	6.6	6.6	0.2	6.0	4.6	0.6
15	6.4	3.8	1.6	6.0	5.1	1.4	6.7	6.7	1.2	6.4	5.2	1.4
16	5.4	3.7	0.9	5.6	5.2	1.3	6.0	6.3	1.0	5.6	5.1	1.1
17	5.8	2.7	0.8	6.0	5.2	1.2	6.6	6.6	0.6	6.2	4.8	0.9
18	5.6	3.2	0.7	5.9	5.0	0.9	6.7	6.7	0.9	6.1	5.0	0.8

[1] 1-9, 9 = best.

[2] Evaluated June 19 (0 = dead, 8 = best).

Table 4.—Effect of treatment and year on yield of three lawngrasses (means of 12 harvest dates in 1978 and 1979)[1]

Treatment no.	St. Augustine		Floratam		Centipede		Yearly means	
	1978	1979	1978	1979	1978	1979	1978	1979
	Grams fresh weight/plot 13 ft²							
1	92	91	90	112	133	109	105	104
2	118	124	107	113	104	120	109	119
3	108	86	126	121	137	139	124	115
4	99	145	85	98	112	126	99	123
5	104	87	87	72	115	123	102	94
6	105	110	104	138	124	189	111	146
7	102	120	107	163	91	140	100	141
8	135	131	134	148	133	182	134	154
9	158	139	160	210	160	232	159	194
10	121	128	125	165	139	173	128	155
11	140	141	165	147	172	184	159	157
12	144	132	152	185	152	217	149	178
13	118	150	128	186	145	231	130	189
14	168	89	200	202	169	246	179	179
15	181	173	187	229	169	292	179	231
16	113	168	135	214	124	231	124	204
17	165	115	174	189	138	228	159	177
18	145	183	174	209	204	292	174	228

[1] Seven days growth, 2½-inch height of cut.

clipping yields (*20*). Evaluation panel members in the lawngrass study considered color as the most important criterion of quality in a lawngrass, with density of somewhat lesser importance. This type of turfgrass is grown primarily for overall esthetic value, rather than the appearance and texture necessary for golf green grasses. The visual rating, however, is still considered the best method of any turf quality evaluation if performed by competent individuals independently of one another (*3*).

Centipede was of significantly higher quality ($P<.05$) in 1978 and 1979 than the other lawngrasses, irrespective of treatment or year in which the N was applied. There was no significant quality difference between St. Augustine and Floratam during the same period of time (Table 2). Yields of centipede also appeared higher than those of the other two grasses, but there were no significant differences in yield among them (Tables 2 and 4). The soil pH, which ranged from 5.4 to 7.0 during this research, may have had an influence on quality of the three grasses. Centipede reportedly attains optimum quality at a pH of 5.0 to 5.7 (*19*). At high pH levels, this grass was lighter green in color than when grown in more acid soil, which is indicative of an iron deficiency. Iron chelate, sprayed on the turf to temporarily alleviate the chlorosis, was recommended (*19*). No data were found in the literature reviewed concerning optimum pH levels for St. Augustine and Floratam turfgrasses, but they are grown on soils in Louisiana that may vary in pH from less than 4.9 to more than 6.9, depending on the location (*7*).

The quality of all lawngrasses was highest in 1978, with centipede showing the least and St. Augustine the largest decrease in 1979, while Floratam was intermediate in this respect (Table 3). All St. Augustine plots in 1979 were below the acceptable quality level of 4.5 on the visual evaluation scale, with only two Floratam plots given similar ratings. Centipede plots were rated from 5.9 to 6.7 in 1979. The highest quality (1978 and 1979 means of all grasses) was observed on the August 23 evaluation date. Quality was lowest on April 25, remaining relatively constant in August but generally decreasing in September (Table 5).

Lawngrass yields (means of three grasses and 2 years) showed no significant differences (Table 4). Although centipede had the highest total fresh weight (means of both years), there were no significant yield differences among grasses. Generally higher yields occurred in 1979 than in 1978 in all three lawngrasses, but St. Augustine showed the smallest difference between years. These data show there was no positive relationship between quality and yield in this study, since quality was highest in 1978, when yields were lowest. The smallest yield in both years was on the April 25 harvest date and the highest on July 16, decreasing in August and September (Table 5). Mean quality of the three grasses was not highest on the same date that yields were largest, again showing the low degree of association between these two plant responses to N treatment and the environmental influences of yearly and monthly climate.

St. Augustine and Floratam lawngrasses were slower to reach high quality levels than centipede, generally not attaining until July the same approximate quality that centipede had reached in May. These data indicate centipede is more tolerant of cooler temperature for growth than the other two grasses, although it is more susceptible to foliar browning when the air temperature is near the freezing point (Tables 6, 7, and 8). Floratam apparently had the highest total yield among the grasses in July (Table 7), but not significantly higher. Yields and quality of the lawngrasses were not related in this study.

Little research concerning lawngrass foliar nutrient concentration has been reported. Limitations presently exist in developing proper sampling techniques and interpreting the results, although the actual analysis may be very accurate for all 16 essential turfgrass elements (*2*). Seasonal fluctuations are considered to be a source of error, along with maturity of the tissue sampled. Considerably more data are necessary on levels of essential nutrients in the tissues of various turfgrass species grown under different fertility levels and environmental conditions for tissue analyses to become more useful in the diagnosis of turfgrass nutrient status (*2, 14, 16*). Lawngrass foliar analyses reported here represent data obtained with the grass species, soil, nutritional levels, and environment previously described.

Table 5.—Influence of treatment and harvest date on quality and yield of all lawngrasses (replication means, 12 harvest dates, 1978 and 1979)

Treatment no.	April 25		May 24		June 19		July 16		August 23		September 27	
	Quality[1]	Yield[2]	Quality[1]	Yield[2]	Quality[1]	Yield[2]	Quality[1]	Yield[2]	Quality[1]	Yield[2]	Quality[1]	Yield[2]
1	4.1	82	5.2	71	5.4	107	5.8	175	6.1	123	5.7	70
2	3.8	81	4.8	69	5.2	105	5.6	209	5.5	132	5.3	90
3	4.1	75	5.7	93	5.7	121	5.7	196	5.8	145	5.5	89
4	4.2	77	5.0	70	5.3	112	5.5	204	5.7	113	5.4	91
5	3.9	56	5.1	64	5.4	89	5.9	174	5.9	127	5.9	79
6	4.4	93	5.4	101	6.2	162	5.7	211	6.0	135	5.2	70
7	4.2	81	5.4	75	5.5	129	5.5	217	5.9	129	5.3	93
8	4.2	76	5.2	86	5.5	163	5.7	276	5.6	157	5.3	106
9	4.4	102	5.9	161	5.9	207	5.6	321	5.6	163	5.6	102
10	4.3	85	5.4	91	5.7	161	5.6	280	5.9	152	5.6	99
11	3.6	85	5.0	107	5.2	142	5.8	327	5.8	178	5.2	114
12	4.3	97	5.1	107	6.4	205	5.3	297	5.8	196	5.1	82
13	4.1	97	5.4	132	5.7	177	5.7	263	5.9	166	6.0	120
14	3.7	100	5.3	138	5.7	198	5.8	337	5.8	208	5.6	122
15	4.5	99	6.1	174	6.2	267	6.1	382	5.9	197	5.8	113
16	4.4	101	5.3	120	5.8	188	5.4	302	5.8	180	5.4	95
17	4.4	65	5.8	131	5.7	183	6.1	325	5.9	188	5.2	117
18	4.4	115	5.2	168	6.4	233	5.7	352	6.2	223	5.5	125

[1] 1-9, 9 = best.

[2] Grams fresh weight/plot 13 ft^2 (7 days growth, 2½-inch height of cut).

Table 6.—Influence of treatment and harvest date on quality and yield of St. Augustine (means of 12 harvest dates and evaluations, six in 1978 and six in 1979)

Treatment	April 25		May 24		June 19		July 16		August 23		September 27	
no.	Quality[1]	Yield[2]	Quality[1]	Yield[2]	Quality[1]	Yield[2]	Quality[1]	Yield[2]	Quality[1]	Yield[2]	Quality[1]	Yield[2]
1	4.0	79	4.9	53	4.5	95	5.4	168	5.7	106	5.0	65
2	3.1	90	4.0	54	4.0	91	4.6	282	3.9	119	3.6	90
3	3.8	66	5.5	73	4.7	83	5.2	167	4.9	112	4.8	82
4	4.6	75	4.8	75	4.4	114	4.9	255	4.6	107	4.8	108
5	3.7	47	5.1	42	4.7	73	5.6	195	5.1	132	5.1	87
6	3.9	63	4.9	63	5.3	128	5.3	227	5.3	102	4.7	68
7	3.8	97	5.1	64	4.6	90	5.2	233	5.1	97	4.3	89
8	3.1	68	4.1	67	4.0	139	4.5	306	3.9	116	3.7	98
9	3.4	87	5.2	107	4.7	125	5.0	316	4.7	133	4.5	92
10	4.4	91	4.8	94	4.7	123	5.1	229	4.6	115	4.6	97
11	2.7	76	4.0	78	3.9	101	4.8	356	4.1	147	3.9	87
12	3.2	77	4.4	47	4.7	115	4.7	337	4.5	156	3.7	81
13	2.8	101	4.2	91	4.2	120	5.1	234	4.6	129	5.1	128
14	2.5	87	4.3	51	3.9	109	4.6	290	4.4	149	3.9	84
15	3.9	87	5.4	122	5.1	184	5.5	422	5.3	150	5.4	99
16	4.0	104	4.9	68	4.6	123	4.7	300	4.6	161	4.3	88
17	3.1	47	4.7	69	4.4	121	5.3	316	4.5	176	3.8	110
18	3.3	82	4.1	88	4.6	135	4.9	370	5.0	156	4.6	88

[1] 1-9, 9 = best.

[2] Grams fresh weight/plot 13 ft^2 (7 days growth, 2½-inch height of cut).

Table 7.—Effect of treatment and harvest date on quality and yield of Floratam (means of 12 harvest dates and evaluations, 1978 and 1979)

Treatment	April 25		May 24		June 19		July 16		August 23		September 27	
no.	Quality[1]	Yield[2]	Quality[1]	Yield[2]	Quality[1]	Yield[2]	Quality[1]	Yield[2]	Quality[1]	Yield[2]	Quality[1]	Yield[2]
1	3.4	64	4.7	47	5.4	113	5.7	187	5.7	132	5.4	67
2	3.0	63	4.8	53	5.3	123	5.8	185	5.6	147	5.5	90
3	3.0	63	5.3	52	5.9	155	5.6	237	5.6	162	5.3	75
4	3.0	51	4.5	38	5.3	106	5.3	177	5.4	107	4.7	70
5	3.0	38	4.9	35	5.4	84	5.7	148	5.6	112	5.6	63
6	3.3	59	5.1	57	6.5	176	5.5	207	5.9	173	4.9	57
7	3.5	58	5.2	56	5.8	161	5.4	270	5.6	174	5.5	92
8	3.8	54	4.9	50	5.7	148	6.0	317	5.8	176	5.6	110
9	3.4	75	6.0	100	6.4	244	5.6	374	5.6	210	5.7	111
10	3.1	56	5.3	53	6.0	171	5.7	314	6.0	187	5.7	89
11	3.1	71	5.2	83	5.4	138	5.9	327	5.9	197	5.5	122
12	3.7	67	5.3	66	7.1	268	5.4	304	6.0	237	5.3	71
13	3.0	54	5.4	87	6.1	172	5.5	311	6.2	199	6.1	111
14	2.6	62	5.2	58	6.3	219	6.1	448	6.0	274	6.0	149
15	3.1	63	6.0	87	6.7	292	5.9	434	5.5	251	5.4	122
16	3.5	73	5.6	84	6.3	220	5.5	357	6.0	219	5.6	94
17	3.8	51	6.0	83	6.2	188	6.2	426	6.3	218	5.4	125
18	3.0	63	5.1	80	7.4	263	5.5	384	6.2	283	5.4	76

[1] 1-9, 9 = best.

[2] Grams fresh weight/plot 13 ft^2 (7 days growth, 2½-inch height of cut).

Table 8.—Influence of treatment and harvest date on quality and yield of centipede (means of 12 harvest dates and evaluations, 1978 and 1979)

Treatment	April 25		May 24		June 19		July 16		August 23		September 27	
no.	Quality[1]	Yield[2]	Quality[1]	Yield[2]	Quality[1]	Yield[2]	Quality[1]	Yield[2]	Quality[1]	Yield[2]	Quality[1]	Yield[2]
1	5.6	124	6.0	113	6.3	112	6.3	169	6.8	131	6.5	79
2	5.3	91	5.6	100	6.4	100	6.3	159	6.9	132	6.8	90
3	5.6	96	6.3	154	6.6	125	6.3	186	6.9	160	6.3	111
4	5.1	105	5.6	95	6.3	116	6.3	180	7.1	126	6.5	96
5	4.8	83	5.4	116	6.1	108	6.3	179	7.1	137	6.8	87
6	6.1	156	6.0	182	6.9	182	6.4	205	6.9	132	6.0	85
7	5.2	89	5.8	105	6.2	137	6.0	150	6.9	118	6.2	98
8	5.6	107	6.6	142	6.7	201	6.7	205	7.2	178	6.6	110
9	6.4	146	6.4	277	6.4	253	6.3	222	6.7	146	6.5	105
10	5.4	107	6.0	126	6.4	189	6.1	248	7.0	155	6.5	112
11	4.8	107	5.7	159	6.1	188	6.7	290	7.3	191	6.6	134
12	6.1	146	5.6	207	7.4	215	6.0	249	7.0	195	6.6	96
13	6.4	135	6.6	219	6.7	239	6.4	244	7.1	169	6.7	121
14	6.0	151	6.3	226	6.8	266	6.7	273	7.1	199	6.8	134
15	6.5	148	6.8	313	6.7	325	6.8	290	7.0	190	6.5	120
16	6.0	127	5.6	207	6.3	221	5.9	248	6.8	160	6.4	103
17	6.2	96	6.6	242	6.3	240	6.8	233	7.1	171	6.5	118
18	6.5	194	6.4	334	7.2	299	6.5	304	7.3	229	6.4	129

[1] 1-9, 9 = best.

[2] Grams fresh weight/plot 13 ft^2 (7 days growth, 2½-inch height of cut).

Foliar nutrient levels in this research were generally lower than those reported (*14, 16*) with other grass species grown under lower temperature and rainfall conditions and differing soil and nutritional levels. Earlier data obtained in N fertility trials with Tifgreen bermudagrass grown in a mostly sand golf green medium with higher levels of N, also showed higher tissue concentrations of some of the same elements reported here (*1*).

Treatment had no apparent influence on any of the foliar nutrient levels studied in this research (Table 9). Nitrogen levels in foliage of the three grasses were especially low compared with those reported for other species, ranging from 2.1 to 2.6 percent instead of 4 to 5 percent. This difference may have been partially due to the amounts of N generally applied being lower, but some treatments contained as much or more of the element than those used in earlier research with Tifgreen bermudagrass and with two of the same sources of N. In addition, more loss of N from leaching would be expected in a golf green medium consisting of 70 percent sand than in the medium-textured soil where the lawngrass study was conducted (*1*). Therefore, the three species of lawngrasses do not seem to be as efficient in the utilization of N as some other species, based on foliar analyses. Quality ratings for Tifgreen, at the same rates of N, were much higher in previous research by the authors than those for the lawngrasses in this study, and the foliar N percentage was correlated (r=0.58**) with grass quality (*1*).

Table 9.—Effect of treatment on foliar nutrient concentration of lawngrasses (means of all grasses and three analyses in 1978)[1] [2]

Treatment no.	N (%)	P (%)	K (%)	Mg (%)	Cu (ppm)	Fe (ppm)
1	2.2	0.52	1.9	0.24	19	27
2	2.3	0.51	1.9	0.23	17	25
3	2.4	0.48	1.9	0.23	18	26
4	2.1	0.51	1.8	0.24	17	26
5	2.3	0.50	1.9	0.24	18	28
6	2.3	0.47	1.9	0.21	19	24
7	2.2	0.50	1.8	0.23	18	26
8	2.5	0.51	2.0	0.25	18	28
9	2.6	0.44	1.9	0.23	18	28
10	2.3	0.50	1.9	0.25	18	28
11	2.5	0.48	1.9	0.23	17	25
12	2.4	0.45	1.9	0.23	17	28
13	2.4	0.50	1.9	0.23	17	26
14	2.6	0.47	1.9	0.22	18	25
15	2.7	0.43	2.0	0.23	18	25
16	2.4	0.49	1.9	0.22	19	25
17	2.5	0.47	1.9	0.23	19	26
18	2.5	0.44	1.9	0.21	17	25

[1] Foliar analysis samples collected on April 25, June 19, and September 27 harvest dates.
[2] Dry weight basis.

Foliar P concentrations in lawngrass clippings were approximately the same as those in Tifgreen bermudagrass, while the percentage of K was somewhat higher (Table 9). The amounts of foliar K in the bermudagrass ranged from 1.5 to 1.9 percent, but generally averaged approximately 1.6 as compared with 1.9 percent in the three lawngrasses. The foliar K concentration was related to turfgrass quality (r=0.16*) in previous research, while the amount of P present in clippings was not associated with panel ratings (*1*). Foliar N alone in this study had no relationship with quality.

The foliar concentrations of Cu were approximately equal to those reported in the literature (*14*), except where Milorganite (activated sewage sludge) was applied. Milorganite contained significant amounts of Cu, which was correlated (r=0.56**) with bermudagrass turf quality (*1*).

Amounts of foliar Mg were higher in the three lawngrasses in this study than those previously reported (*1*), but again leaf Mg was not associated with quality. Magnesium levels in grass clippings from plots fertilized with Milorganite, which contains some Mg, were approximately the same as those in clippings from plots treated with fertilizers that did not have any Mg (*1*).

The foliar Fe content of the grasses (Table 10) was considerably lower than that of Tifgreen bermudagrass (200 to 400 ppm), even where the same two N sources were utilized in earlier research (*1*). The topsoil in the research reported here contained higher amounts of Fe—49 to 188 ppm compared with 49 to 66 ppm in the bermudagrass medium. This may indicate the bermudagrass species was more efficient in utilization of Fe than the three lawngrass species, or that its Fe requirement was higher. Overall turfgrass quality was not influenced by foliar Fe concentration in either this or the earlier research, perhaps showing that critical levels of this element in the grass foliage had been attained or surpassed.

The amount of foliar P was significantly lower ($P<.05$) in centipede than in the other grasses (Table 10). Among varieties, foliar P was not directly associated with quality, since centipede was given higher panel evaluation

Table 10.—Foliar concentrations of P, Cu, and Fe in three lawngrasses (means of three analyses in 1978)[1]

St. Augustine			Floratam			Centipede		
P[2] (%)	Cu[2] (%)	Fe[3] (ppm)	P[2] (%)	Cu[2] (%)	Fe[3] (ppm)	P[2] (%)	Cu[2] (%)	Fe[3] (ppm)
0.53[a]	18[b]	24	0.56[a]	22[a]	26	0.36[b]	13[c]	25

[1] Dry weight bosis, samples collected an April 25, July 16, ond September 27 harvest dotes.

[2] Mean separation, Duncon's Multiple Range Test; within nutrient means with at least one letter in common ore nat different at the 5% level.

[3] No significant difference.

ratings ($P<.05$). Centipede reportedly requires only small amounts of this element, and medium to high amounts of soil P made Fe unavailable to this turfgrass in a previous study (*19*). However, in this study the foliar levels of these two elements did not influence the quality of centipede, but may have had some indirect influence on the Floratam and St. Augustine turfgrasses.

Perhaps the most significant data obtained in this research was that which pointed out the influence of N rates, application dates, and low temperatures on quality of the lawngrasses (means of all N treatments, Tables 2 and 3). The evaluation on June 19, 1980 (Table 2) showed that cold damage during the winters of 1978-79 and 1979-80 resulted in the death of about 85 percent of all the turfgrasses, with little or no reestablishment occurring, based on evaluations in July, August, and September of 1980. The quality decrease began in the winter of 1978-79, with all three grasses being rated lower in 1979 than in 1978. St. Augustine showed the greatest decline from 1978 to 1979 (41 percent), followed by Floratam (13 percent). Centipede showed the least decline (2 percent), with some plots even improving in quality during that time. All St. Augustine plots, and one of Floratam, were rated below the acceptable quality level of 4.5 in 1979, but no centipede treatment was below 5.9 that year (Table 3). In 1978, St. Augustine and Floratam were of the same quality (5.6) in mean ratings, including all N treatments, while centipede was ranked at a level of 6.4. During 1979, St. Augustine was evaluated at 3.3, Floratam at 4.9, and centipede at 6.3. However, centipede and Floratam showed the greatest decline in quality in 1980, each decreasing approximately 70 percent, compared with a decline of about 50 percent for St. Augustine by June 19 of that year.

Some research has shown that N rates from 6 to 12 pounds per 1,000 square feet (April to October) resulted in greater winter injury to St. Augustine and Floratam turfgrasses than rates from 0 to 3 pounds (*18*). Others have reported that the least amount of cold damage to St. Augustine occurred when N was not applied after September, with the greatest damage being done when N was applied in November and December (*27*). A study with centipedegrass showed that N rates of 1 to 2 pounds per 1,000 square feet per year promoted greater susceptibility to winter injury. Nitrogen rates of ¼ to ½ pound per 1,000 square feet were considered adequate for color and growth without promoting excess thatch and higher susceptibility to cold damage (*23*). Centipede decline is believed to be due to over fertilization with N and accumulation of thatch, causing large chlorotic (yellow) patches in late summer or early fall and subsequent death of the grass in these areas. Centipede decline usually required several years to affect this grass, but the application of 1 or 2 pounds of N per 1,000 square feet per year and small amounts of Fe, with low to medium P levels, prevented or controlled the problem in other areas (*13*).

The N rates in this study were generally higher than those that most Louisiana lawngrasses receive. Many lawns in Louisiana are never fertilized with nitrogen. However, this study was designed to determine the influence of N rates and application dates that a large number of homeowners and others use on their turfgrasses (3 pounds per 1,000 square feet per year). Those who contract with lawn-care companies for such services generally have from 3 to 6 or more pounds of N applied on a regular basis during the year. Some lawn-care companies also suggest that lawns be fertilized with N (and/or P and K) during December, January, and February, often in combination with pesticides. Cold injury to the turfgrasses was anticipated in this study, with the objective of determining the rates and timing of N that might provide data for future research with other (lower) rates, application dates, and sources of the element.

The results showed that N rates of 3 or more pounds per 1,000 square feet per year were too high for the turfgrasses used and the conditions that existed during this study. Applications of N at annual rates of 3 to 9 pounds should not be made after September 1 because new growth resulting from fertilization may not reach proper maturity before temperatures fall low enough to cause cold damage. Temperatures at the Burden Research Center in Baton Rouge during 1978 reached minimums of 44°F on October 9, 38°F on November 9, and 26°F on December 7. The mean minimum temperature during December was 41°F, with the lowest reading of 25°F occurring on December 12.

The average minimum temperature during the last week of December, 1978, was about 50°F, with the maximum about 65°F. The lowest minimum temperatures during this research, however, were on January 2 and 3 of 1979, 16° and 15°F, with maximums of only 27° and 38°F, respectively—a drastic decrease in minimum temperatures within 10 days. The mean minimum temperature during the first week of January, 1979, was below freezing (31°F). These temperatures were probably the factor contributing most to the lower quality ratings given to all lawngrasses in the 1979 growing season, and influenced St. Augustine more than Floratam or centipede. Rainfall and temperatures during April to October in 1978 and 1979 showed no significant differences, which might otherwise have influenced this plant response. The lowest minimum temperatures during the winter of 1979 and 1980 were 24°F on February 1 and 22°F on March 2 and 3 of 1980. The 25-year weather records for Baton Rouge show that the mean date when a 24°F or lower temperature occurs is January 21, with a 75 percent chance that these minimums may occur as early as January 11, and only a 10 percent chance of occurrence by January 8. The mean minimum temperature in January of 1979 was 33°F, while it was 44°F in January of 1980. The 25-year mean minimum January temperature in Baton Rouge is 40.4°F, so the average of 33°F in January of 1979 was 7.4 degrees lower, with minimums of 17°F and 18°F on January 9 and 15, 1979, respectively.

Research has been conducted in Mississippi on the effects of low temperatures on centipedegrass at several levels of N, P, and K (*26*). The results indicated that soil fertility levels did influence the cold tolerance of this lawngrass. A minimum of approximately 4 pounds of N per 1,000 square feet was needed to obtain acceptable quality, but higher rates resulted in decreased cold tolerance. Phosphorus fertilization had little effect on the hardiness of this turfgrass, but K fertilization increased hardiness. It was concluded that for home lawns under these conditions, centipede should be fertilized with approximately 4 pounds of N, 2 pounds of P_2O_5, and 4 pounds of K_2O per 1,000 square feet annually.

Rates of K used in the research described here were considerably lower than those reported above, averaging only about 2 pounds or less of K_2O per 1,000 square feet per year. Potassium is difficult to maintain in constant supply in the soil for turfgrass growth as it is heavily leached by rainfall in some soils in Louisiana, becoming unavailable to the plant. Cold damage to St. Augustine, Floratam, and centipede from N applications and low temperatures might have been lower if the K rates and/or frequencies of application had been higher. Future research will be conducted using lower rates of N and larger amounts of P and K to determine their possible influences on the quality, growth, and cold hardiness of these lawngrasses in Louisiana.

Summary

Nitrogen source, rate, or frequency of application generally had no significant influence on the quality or yield of centipede, St. Augustine, or Floratam lawngrasses in 1978 and 1979. Centipede, however, was of significantly higher quality during that period than either of the other two grasses, and also appeared to outyield them.

Treatment (N source, rate, or frequency) did not significantly affect concentrations of the foliar nutrients studied in this research. Levels of elements in grass clippings were generally lower than those reported with other species grown in different environments and soils and under different nutritional conditions.

Winter damage, irrespective of treatment, resulted in the death of 85 percent of all lawngrasses by June of 1980. The greatest injury occurred during the winter of 1978-79, being less severe in the winter of 1979-80 when temperatures were more moderate.

Nitrogen rates of 3 pounds or more per 1,000 square feet per year should not be used on these turfgrasses, grown under the described conditions, nor should any N be applied after September 1. Lower N rates, along with P and higher amounts or frequencies of K, appear necessary to reduce or avoid cold injury to the three lawngrasses most generally grown in Louisiana.

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Straightbred and Crossbred Beef Cattle Performance in Louisiana

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The Louisiana Agricultural Experiment Station follows a nondiscriminatory policy in programs and employment.

COVER PICTURE

A Brahman X Hereford cow with her Angus sired calf graze Coastal bermudagrass on the Red River Valley Agricultural Experiment Station at Bossier City, La., at weaning time (July 15, 1981). Cow No. 416, shown here, produced and weaned five calves by the age of 7 years. The calves were all sired by Angus bulls, and the average weaning weight of her four heifer and one steer calves was 556 pounds.

Cow Data
Cow No.: 416
Breed: ½ Brahman, ½ Hereford
Age: 7 years
Weight: 1,150 pounds

Calf Data
Calf No.: 113
Breed: ½ Angus, ¼ Brahman, ¼ Hereford
Age: 299 days
Sex: steer
Weaning weight: 660 pounds
Grade: 15 (low fancy)
W.P.D.A.: 2:21 pounds
Calf value: $429

Straightbred and Crossbred Beef Cattle Performance in Louisiana

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K. L. KOONCE[3] AND D. K. BABCOCK[3]

The primary goal of a cow-calf producer is to have each cow in his herd wean one heavy calf each year. Maximum improvement in reproduction and calf weaning weight probably will come through a combination of improved heredity and environmental factors. Available research indicates that the use of crossbred females in a well planned beef crossbreeding program significantly increases cow reproduction and calf weaning weight.

Information is limited on the performance under southern climatic conditions of the recently introduced Continental European or exotic breeds when crossed with the traditional British breeds. Previous research at the Louisiana Agricultural Experiment Station has demonstrated that firstcross Brahman cows were generally superior to straightbred and other firstcross cows for reproduction and maternal traits. Maternal ability includes milk production, general care, and protection provided by the beef female for development of her calf both before and after birth and up to weaning time. With these facts in mind, a project was initiated on alluvial soils at the Red River Valley Agricultural Experiment Station, Bossier City, to (1) compare the growth performance of Hereford calves with the growth performance of crossbred Brahman and Continental European-sired calves from Hereford dams in the first phase and; (2) to compare in Phase II of the study the maternal performance of the straightbred Hereford with that of crossbred cows produced in Phase I.

EXPERIMENTAL PROCEDURE

Phase I

Cow Herd Management

Hereford cows averaging 6.9 years of age were artificially bred in an estrus synchronization project to produce calves for this study. The base cattle herd had been enrolled in a performance testing program for 15 years prior to the initiation of the study, and all replacement heifers were selected from this herd. Cows were culled for either low reproduction or low calf weaning weights, and the herd was considered to be a highly productive commercial herd. Birth and weaning weights were obtained for 233 calves born during three fall calving seasons (1971 through 1973). The calves were produced by artifically breeding Hereford cows with semen from Brahman, Limousin, Maine-Anjou, and Simmental sires. Following the artificial insemination (AI) period, Hereford bulls were placed with the cows for cleanup breeding. Over the 3-year period four to six sires per sire breed were used to produce the calves. Although the Hereford calves were born later in the calving season than AI calves, they were not extremely late calves because Hereford bulls were placed with the cows between the first and second synchronized AI periods as well as after the second AI period.

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Difficult calving was not a problem with mature Hereford cows calving Brahman-, Limousin-, Maine-Anjou-, or Simmental-sired calves. A high percentage of 3-year-old first-calf heifers bred to the larger exotic beef breeds, however, were assisted at calving.

The cows were bred during a 75-day breeding season from December 5 to February 20 to calve between September 15 and December 1. The dams were approximately 36 months of age when they first calved. All male calves were castrated at birth. The calves did not receive any creep feed and remained with their dams until weaned at an average age of 270 days. Each year cow and calf weights were recorded on December 1, April 1, and July 15, and the calves were graded by the same Louisiana Cooperative Extension Service Beef Specialist at each July 15 weaning date.

All calves were vaccinated with a seven-way vaccine for blackleg and other clostridial diseases. Brood cows were vaccinated annually for vibriosis and leptospirosis and each cow received an injection of Vitamin A prior to the breeding season. Cows were wormed twice in the fall and twice in the spring, 14 to 21 days apart, to control internal parasites. The calves were wormed once when they were approximately 6 months old. External parasites on the cows and calves were controlled by spraying or dusting as needed.

The cows were stocked at the rate of approximately one cow per acre throughout the study. During the fall calving season the cows grazed Coastal bermudagrass pastures with additional Coastal hay and protein supplement supplied as needed during the late fall and early winter. During the winter and spring the cows and calves grazed pastures containing either a wheat-ryegrass mixture planted on a prepared seed bed, or fescue-Sl clover mixtures, or sod planted ryegrass on Coastal bermudagrass pasture. High quality Coastal bermudagrass and sorghum-sudangrass pastures were provided for the cows and calves during the summer up to the time of weaning on July 15. All pastures were highly fertilized in split applications and any excess forage was harvested for hay.

Postweaning Management

Postweaning data were obtained for 233 steers and heifers weaned during the 3 years of Phase I (1972 through 1974). Following a 2-week weaning adjustment, the calves were placed together in one group and allowed to graze sorghum-sundangrass pastures beginning August 1 each year and then rotated to Coastal bermudagrass pastures. The steers and heifers continued to graze Coastal bermudagrass pastures during the late fall, and hay was fed as needed until winter pastures were available for grazing, usually in early January. Yearling steers and heifers were grazed on wheat-ryegrass pastures throughout the winter and spring. The yearlings grazed the second summer and early fall on Coastal bermudagrass and sorghum-sudangrass pastures. The animals did not receive any supplemental protein or grain during any of the grazing period. This type of management grazing system continued three consecutive grazing seasons (1972 to 1975). The stocking rate throughout the postweaning phase was approximately two head per acre.

Postweaning weights were recorded as initial weights 2 weeks after weaning and as final weights when the animals were long yearlings. Intermediate weights were also obtained after each seasonal (summer or winter) grazing period.

All weights were recorded using the same weighing conditions and the animals remained in one group throughout each of the 3 grazing years. The steers were not implanted with a growth promotant, but both steers and heifers were wormed once in the fall and once in the spring each year. External parasites were controlled by spraying or dusting as needed.

Year one ages when yearling and long yearling weights were obtained differed from the ages at weighing times in years two and three. In year one average yearling and long yearling ages were 348 and 581 days, respectively. In years two and three average yearling and long yearling ages were 397 and 683 days, respectively.

Phase II

The Brahman x Hereford, Limousin x Hereford, Maine-Anjou x Hereford, Simmental x Hereford, and straightbred Hereford cows, produced in Phase I, were used in the 4-year study of Phase II. Each year heifers and mature cows were bred to performance tested Angus bulls, highly selected for growth rate, during a 75-day breeding season from early December to mid-February to calve between September 15 and December 1 of the subsequent year. Performance data were obtained on 325 Angus sired two and three way cross calves born during four fall-calving seasons (1975 through 1978). The cows ranged in age at calving from 3 to 7 years and were divided into single sire breeding groups of 25 to 30 cows during the breeding season. Each of the different breed types was represented in all sire breeding groups. After the breeding season all cows were maintained in a single herd.

The cows used in Phase II were managed similarly to those in Phase I with regard to pastures, supplemental feeding, stocking rates, pasture fertilization and herd health practices. Cow and calf weights were also recorded as in Phase I. Calves were again weaned on July 15 each year at an average age of 274 days. Calves were not creep fed because it would interfere with maternal evaluation of the dam breeds. All calves were individually priced by the same auction barn manager each year and graded by a beef specialist at weaning time.

Statistical Analysis

The data were statistically analyzed by least-squares procedures. Because yearling and long yearling ages varied from year to year in Phase I, the effects of variation in calf age were removed in a preliminary analysis. The detailed mathematical models employed are outlined in the appendix.

RESULTS AND DISCUSSION

Calf Growth, Phase I

Results of Phase I are presented in Table 1. Year differences were important ($P<.01$) for weaning and postweaning growth traits, but differences did not occur for birth weight. Birth weights varied from a low of 74.6 pounds in 1974 to a high of 75.2 pounds in 1973. This small variation in birth weight suggests that the in-utero environment provided to the fetus was adequate to offset any yearly variations that existed in forage quality and climatic conditions. Variations observed in calf weaning weight, yearling weight and long yearling weight are typical of yearly differences that exist in beef operations.

Table 1.—Least Squares Year Means and Standard Errors for Growth Traits, Phase I

Year	No. of calves	Weight, lbs.			
		Birth	Weaning**	Yearling**	Long yearling**
1972	84	74.9±1.2	475.2±8.2	549.8± 9.1	803.6±9.5
1973	83	75.2±1.3	465.3±8.8	562.7± 9.3	794.5±9.7
1974	66	74.6±1.4	434.0±9.4	518.7±10.5	756.9±10.9

**Significant year differences, $P<.01$.

Breed-of-calf differences (Table 2) were quite pronounced (P<.01) for weights of the calves at all ages and include both breed and mating type (straightbred and crossbred) influences. Straightbred Herefords were smaller than any of the crossbred groups at birth and all subsequent ages. Brahman-sired crossbreds performed similarly to the average of the three Continental European-sired crossbred groups (Limousin, Maine-Anjou and Simmental) through weaning. Subsequently they had higher growth performance than any of the other crossbred groups. This is depicted graphically in Figure 1. The superior postweaning performance of Brahman crossbred cattle on forage diets has been observed consistently at this location and at other experiment stations throughout Louisiana.

Table 2.—Least Squares Calf Breeding Means and Standard Errors for Growth Traits, Phase I

Calf Breeding	No. of calves	Weight, lbs. Birth**	Weaning**	Yearling**	Long yearling**
H	108	65.9± .9	411.5± 6.8	497.9± 6.6	725.3± 6.9
BxH	33	76.5±1.7	470.4±10.7	593.1±12.2	838.6±12.6
LxH	44	75.4±1.5	451.0±10.4	532.3±11.3	768.8±11.7
MAxH	26	78.7±2.0	484.8±14.1	542.9±14.8	804.9±15.4
SxH	22	77.9±2.1	473.1±14.7	552.5±15.6	787.3±16.2

[a]Breeds are coded: H= Hereford; BxH = Brahman x Hereford; LxH = Limousin x Hereford; MAxH = Maine-Anjou x Hereford; SxH = Simmental x Hereford.

**Significant calf breeding differences, P<.01.

Among the Continental-sired crossbred groups, Maine-Anjou calves were the heaviest at all ages except at a year of age when the Simmental crosses weighed the most. Williamson and Humes (1980) reported on a study conducted in south Louisiana in which Brahman, Chianina, Maine-Anjou and Simmental bulls were bred to Angus and Hereford cows. In their study no breed-of-sire differences were detected for weaning weight, but the Braham sired calves were 11 and 12 pounds heavier than Maine-Anjou and Simmental sired calves, respectively. From the results of these two studies it would appear that any additive genetic superiority for preweaning growth of the Continental breeds may be offset by greater levels of heterosis of the Brahman crosses in Louisiana environments.

While weights at given ages are very important in determing economic merit of various breeds and breed crosses, weight gains during various stages of growth are also important. For example, growth from birth to weaning is of primary importance to the cow-calf producer whereas postweaning growth is of major interest to the producers in the stocker phase of

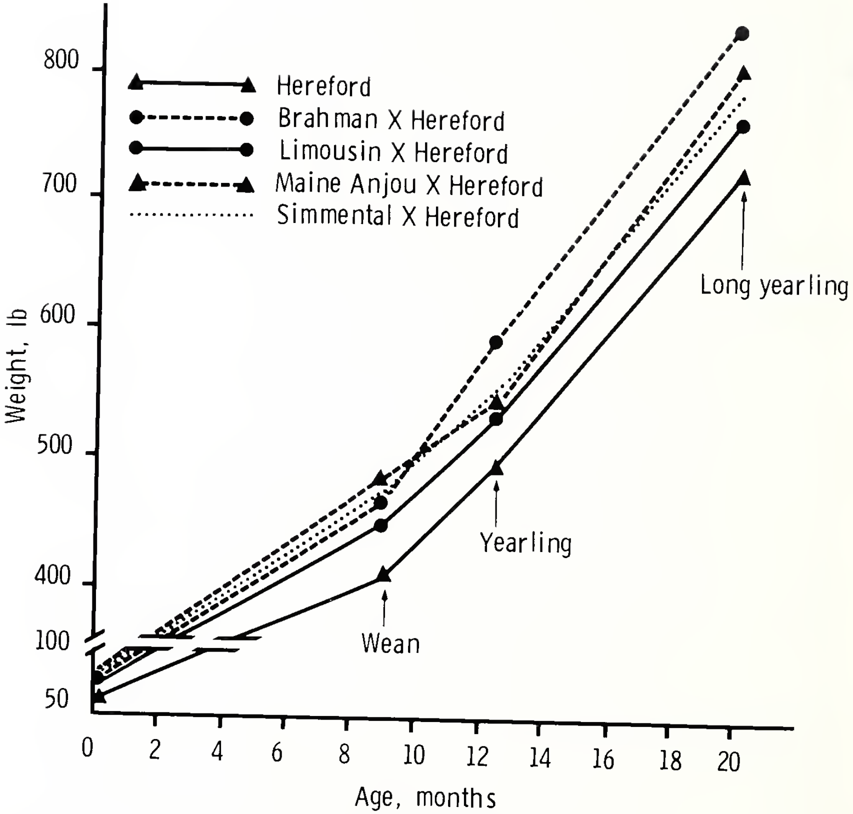

Figure 1.—Growth of Phase 1 calves by breeding of calf.

beef production. Therefore, weight gains for various periods were calculated and are presented in Table 3. Weight gains from birth to weaning were similar for the Brahman, Maine-Anjou and Simmental crosses, with the Limousin crosses being intermediate between straightbred Herefords and other crossbred groups. In the postweaning phase, the most striking observation was the superior performance of the Brahman crosses from weaning to a year of age. This interval occurred from mid-summer to fall when forage quality was at its lowest and vividly demonstrates an adaptive advantage for the Brahman crosses at this time. Also, heat stress, at its highest in July, August and September, may have been a contributing factor. Most of the postweaning weight advantage of Brahman crosses was generated during this period as their weight gains through the winter and subsequent summer were similar to the gains of other breed crosses.

Table 3.—Weight Gains for Various Stages of Growth in Hereford and Crossbred Cattle, Phase I

Calf breed[a]	Birth to weaning, lbs.[b]	Weaning to yearling wt., lbs.	Yearling wt. to long yearling wt., lbs.	Total postweaning gain, lbs.
H	345.6	86.4	227.4	313.8
BxH	393.9	122.7	245.5	368.2
LxH	375.6	81.3	236.5	317.8
MAxH	406.1	58.1	262.0	320.1
SxH	395.2	79.4	234.8	314.2

[a] Breeds are coded: H= Hereford; BxH = Brahman x Hereford; LxH = Limousin x Hereford; MAxH = Maine-Anjou x Hereford; SxH = Simmental x Hereford.

[b] Obtained by subtracting birth weight from weaning weight for each breed group.

In this study, Hereford cattle grew at approximately the same rate following weaning as the Continental-sired crosses. While calves sired by large, growthy breeds might be expected to outgain British breed cattle, such was not the case in this study. Had the cattle been placed in a feedlot following weaning, perhaps the large-framed Continental-sired calves would have had higher growth rates than the straightbred Herefords. With rising grain prices, this does not seem to be an economical system of beef production. Based on these results a stocker operator might observe little, if any, increase in postweaning gains from the large-framed Continental crosses greater than gains for Hereford or Hereford x Angus calves.

Crossbred superiority at weaning appears to be the result of a combination of factors, including heavier birth weights, hybrid vigor (heterosis) and superior early growth. It has been well established that larger birth weights are associated with higher growth rate, particularly from birth to weaning. Of the 58.3-pound weaning advantage of the crossbred calves over the Herefords, 11.2 pounds (19.2 percent) reflected birth weight differences. The large crossbred calves were probably more aggressive in their nursing habits which would tend to magnify the birth effect. Although it was not possible to estimate heterosis in this study, it has been observed repeatedly for weaning weight in designed crossbreeding studies. In a review article of crossbreeding studies from Nebraska, Cundiff (1975) reported that crossbred calves exhibited an average advantage of 19.4 pounds (4.6 percent heterosis) over the purebreds. Crossbred calves were also 2.7 pounds heavier at birth than the purebreds. Turner and McDonald (1972), reporting the results of a crossbreeding experiment involving Angus, Brahman, Brangus and Hereford cattle at LSU, observed that singlecross steer and heifer calves were 41.6 and 35.0 pounds heavier, respectively than their straightbred contemporaries.

Cow Production, Phase II

In Phase II, year differences were quite large (P<.01) for percent calf crop born and weaned (Table 4). These differences reflect how climatic and nutritional differences markedly affected reproduction and calf livability in this cow herd. The highest percent calf crop born occurred in the fall of 1976 and 1977 following the mild winters of 1975 and 1976 when the cows were bred. In the fourth year of the study (1977 breeding season and 1978 calving season) much more severe weather was encountered, particularly during the breeding season from December to mid-February which resulted in a greatly reduced conception rate.

Table 4.—Least Squares Means and Standard Errors for Percent Calf Crop Born and Weaned By Year, Phase II

Year	No. of Cow exposures	Percent calf crop ± S.E. Born**	Weaned**
1975	63	80.9±5.3	77.7±6.0
1976	95	91.9±4.2	86.2±4.8
1977	119	88.8±4.0	85.3±4.6
1978	131	71.0±4.6	67.1±5.3

**Significant year differences, P<.01.

As presented in Table 5, large year differences (P<.01) were observed for all calf traits except birth date. Significant year to year variation (P<.01) was also observed in cow weight at weaning. As evidenced by the heavier calf and cow weights, the 1975-1976 and 1976-1977 grazing seasons were decidedly superior to the last 2 years for fall-calving cows in north Louisiana. The abnormally cold weather encountered for long periods severely retarded the growth of winter pastures until early spring in 1977-1978 and 1978-1979 which had an unusually depressing effect on cow and calf weights at this location. The variation of 135 pounds in calf weaning weight from the best to poorest year is a much larger difference than normally expected, but it is indicative of the climatic extremes encountered in this particular 4-year period in north Louisiana.

Table 5.—Least Squares Means and Standard Errors for Cow Production and Weight By Year, Phase II

Year[a]	No. of calves	Birth date, day[b]	Birth** wt., lbs.	Wean** wt., lbs.	Calf grade	July cow** wt., lbs.
1976	49	285.6±4.6	68.9±1.7	556.3±9.0	12.5±.2	1106.5±15.1
1977	79	291.2±3.4	74.0±1.3	533.7±6.6	12.3±.1	1115.5±11.0
1978	106	282.7±3.3	71.6±1.2	467.3±6.5	11.7±.1	1013.6±10.9
1979	91	281.1±4.6	67.1±1.7	431.6±9.1	11.9±.2	976.3±15.3

[a] Denotes year when weaning occurred; e.g., calves born in the fall of 1975 were weaned in the summer of 1976.

[b] Based on the Julian birthdate, counting January 1 as day one.

**Significant year differences, P<.01.

Cow breed differences were not significant for either measure of cow reproduction (Table 6). The percent calf crop born was very similar for all groups except the Maine-Anjou x Hereford cows which had the lowest calving rate (76.4 percent). For weaning rate, Simmental x Hereford cows showed a slight superiority because no calf losses from birth to weaning occurred in this group. Calf losses from birth to weaning were similar for the Limousin x Hereford (7.9 percent), Hereford (7.8 percent) and Brahman x Hereford cows (8.0 percent).

Table 6.—Least Squares Means and Standard Errors for Percent Calf Crop Born and Weaned By Cow Breed, Phase II

Cow breed	No. of Cow exposures	Percent calf crop ± S.E. Born	Percent calf crop ± S.E. Weaned
Hereford	137	85.9±3.0	78.1±3.4
Brahman x Hereford	138	85.0±3.9	77.0±4.5
Limousin x Hereford	66	84.1±4.3	76.2±4.9
Maine-Anjou x Hereford	33	76.4±6.1	73.7±6.9
Simmental x Hereford	34	84.3±6.0	84.0±6.8

The lack of superiority of the crossbred cows over the Hereford cows for reproduction and calf livability is not consistent with most crossbreeding studies. Turner *et al.* (1968) reported large levels of heterosis for reproduction in crosses of Angus, Brahman, Brangus and Hereford cattle. Of the 12 crossbred cow groups in their study, all except the Angus x Brangus cross had higher reproductive rates than the average of their respective purebred contemporaries. Calving rates of 84.7 percent and 65.6 percent were reported for Brahman x Hereford and Hereford dams, respectively. In their study the cows calved in the spring rather than in the fall which may have accounted partially for the low reproduction of the Hereford cows. In another study reported by Meade *et al.* (1981), significant breed-of-dam differences were obtained for calving rate in a spring calving herd. Brahman crosses had the highest calving rate (76.4 percent) followed by Maine-Anjou (71.6 percent), Simmental (62.8 percent) and Chianina (62.5 percent) crosses. Results of these studies, all conducted in Louisiana, suggest that purebred Hereford and crossbred Simmental cows may have relatively high reproductive rates in fall calving herds but may be inferior to crossbred Brahman cows in spring calving herds.

Cow breed differences were observed in calf weaning weight and calf grade at weaning, but no differences were observed in birth date (calving date) or birth weight (Table 7). Although mean birth dates appear to vary considerably from group to group (day 278.6 to day 293.6), the large amount of variation observed within each breed group prevented the differences in birth date from being statistically significant. Generally crossbred Brahman cows calved later which might be expected since the Brahman breed is noted for having a longer gestation period than most *Bos taurus* (non-humped) beef breeds.

Brahman x Hereford cows weaned the heaviest calves in every year except 1976 when the Simmental x Hereford cows ranked first. Averaged across years the Simmental x Hereford cows ranked second and the Hereford cows weaned the lightest calves each year. Performance of the Limousin and Maine-Anjou crosses were similar and intermediate between the straightbred Herefords and crossbred Simmentals for calf weaning weight.

Table 7.—Least Squares Means and Standard Errors for Cow Birth and Weaning Production Traits by Cow Breed, Phase II

Cow breed[a]	No. of calves	Birth date, day[b]	Birth wt., lbs.	Wean** wt., lbs.	ADG** April-July	Calf grade**
H	106	283.4±2.6	69.3±1.0	444.1± 3.0	1.47±.03	11.4±.1
BxH	114	293.6±3.5	71.6±1.3	541.9± 6.8	1.65±.03	12.8±.1
LxH	53	285.3±3.7	69.3±1.4	487.2± 7.3	1.60±.04	12.0±.2
MAxH	25	278.6±5.7	68.6±2.1	487.5±11.1	1.57±.06	12.1±.2
SxH	27	284.8±5.1	73.1±1.9	525.4±10.0	1.83±.05	12.2±.2

[a] Breeds are coded: H= Hereford; BxH = Brahman x Hereford; LxH = Limousin x Hereford; MAxH = Maine-Anjou x Hereford; SxH = Simmental x Hereford.

[b] Based on the Julian birth date, counting January 1 as day one.

**Significant cow breed differences, $P<.01$.

Breed-of-dam rankings were not consistent across all years as evidenced by the significant year x cow breed interaction. As mentioned earlier, the Brahman crosses ranked first in all years except in the first year of the study. The Hereford cows weaned the lightest weight calves in each year. The Simmental crosses weaned the heaviest calves in 1976, the second heaviest calves in 1977 and 1978 and ranked third in 1979. The Limousin and Maine-Anjou crosses ranked third or fourth in each year except in 1979 when the Maine Anjou x Hereford cows ranked second ahead of the Simmental crosses. No apparent reason exists as to why the year x breed-of-dam interaction occurred for weaning weight. With the 4 years combined, however, the weaning weight averages should be reasonably representative of the performance of the breeds over several years.

It is generally accepted that differences exist among breeds of cattle in their lactation persistency. Generally beef cows will not lactate as long as dairy cows, and in some instances beef cows will actually cease lactating and wean their calves prior to a normal time for weaning. Because of their dams' lower lactation potential and shorter lactation period, beef calves are frequently weaned at approximately 7 months of age. This is the reason for using the standard 205-day adjusted weaning weights in performance testing programs. In the South where longer growing seasons are available, it is advantageous to allow calves to nurse their dams as long as possible. Therefore, in this study, calves were weighed in April at an average age of 168.8 days and again 105 days later at the July weaning date.

In the last 105 days before weaning, variation among the cow breeds was again observed for calf average daily gain (Table 7). The breeds generally ranked the same as at weaning, except Simmental crosses had higher gains than Brahman crosses. This would suggest that Simmental crosses are more persistent and will lactate longer than the other crosses. Forage quality and quantity is at its peak during these months, which also might explain the superior performance of the Simmental crosses during this season.

For calf grade at weaning, cow breed differences were large ($P<.01$), and breed rankings were the same as for weaning weights. This is not surprising since calf grade was a subjective score, and graders usually tend to score larger calves highers than smaller calves. In most studies where this relationship has been investigated, the correlation between weaning weight and calf grade has been quite large.

Although production per cow is important in breed evaluation studies, it is more important to obtain some measure of biological efficiency taking into account cow size. Cow weights and measures of weaning efficiency are presented in Table 8. Large differences ($P<.01$) in cow weights were observed among the breed groups and ranged from a high of 1,102 pounds for Maine-Anjou crosses to a low of 963 pounds for Hereford cows, a difference of 139 pounds.

The measure of pounds of calf per pound of cow weaning a calf was obtained by dividing calf weaning weight by cow weight. Highly significant breed differences were obtained for this measure, and the breeds ranked in the same order as for weaning weight except the Maine-Anjoy crosses dropped from third to last (Table 8). This was partially the result of the large size of these cows which caused the low efficiency of .44 pound of calf weaned per pound of cow weaning a calf.

Herd efficiency, measured in pounds of calf weaned per pound of cow maintained in the herd, is calculated by multiplying percent calf crop weaned by the pounds of calf weaned per pound of cow weaning a calf. This measure was not subjected to a statistical analysis, but it would appear that the Simmental and Brahman crosses were the most efficient followed by the Hereford, Limousin x Hereford and Maine-Anjou x Hereford crosses, in that order.

Table 8.—Weaning Efficiency by Cow Breed, Phase II

		Lb. of calf per lb. cow		Dollar return per		
Cow breed[a]	July** cow wt.	Weaning** a calf	Maintained in herd[b]	Cow weaning** a calf	Cow maintained[b]	1,000 lbs. of cow maintained[b]
H	963	.462	.361	229.56	179.29	186.17
BxH	1,081	.504	.388	270.37	208.18	192.59
LxH	1,036	.472	.360	239.01	182.13	175.80
MAxH	1,102	.444	.327	246.18	181.43	164.60
SxH	1,083	.487	.409	253.82	213.21	196.87

[a] Breeds are coded: H= Hereford; BxH = Brahman x Hereford; LxH = Limousin x Hereford; MAxH = Maine-Anjou x Hereford; SxH = Simmental x Hereford.

[b] Not subjected to statistical analysis.

**Significant cow breed differences, $P<.01$.

Cash return per cow is also an important measure of efficiency. It is determined by the quantity and quality of the calf produced. On the basis of return per cow weaning a calf, the Brahman x Hereford crosses returned $16.55 more than the second ranked Simmental x Hereford cows and $40.81 more than Hereford cows. When cow size and reproduction differences were accounted for, however, the magnitude of the differences and breed rankings changed markedly. If cash return is expressed on the basis of a 1,000-pound cow maintained in the herd, the Brahman and Simmental crosses were similar in dollar return. The Brahman x Hereford cows produced heavier calves, but this advantage was offset by the higher weaning rate of the Simmental x Hereford cows. Suprisingly, Hereford cows were intermediate in overall efficiency when expressed as pounds of calf weaned or dollar returned per unit cow weight maintained in the herd. This resulted because of the small cow size and high weaning rate of the Herefords compared to the Limousin and Maine-Anjou crosses.

Results of the present study confirm the production advantages of crossbred Brahman cows reported by Turner and McDonald, 1972 and Meade *et al.*, 1981, although the latter authors reported a larger difference in calf weaning weight between Brahman and Simmental crosses (465.4 *vs.* 402.2 pounds) than was observed in this study. Again, this may be explained partially by the fact that the cows calved in the spring in the study reported by Meade *et al.* (1981) compared with the cows that calved in the fall in this study.

SUMMARY

A two-phase crossbreeding study was conducted over a 9-year period to compare the growth performance of Hereford, Brahman x Hereford, Limousin x Hereford, Maine-Anjou x Hereford and Simmental x Hereford calves and to evaluate maternal performance of the heifers produced in the first phase of the experiment. Crossbred calves produced in the first phase were heavier than Hereford calves at all weighing periods from birth through the long yearling weight. The crossbreds were 17.0 percent heavier at birth, 14.2 percent heavier at weaning, 11.5 percent larger at a year of age and 10.3 percent larger at the long yearling weight than the Hereford calves. Most of the crossbred advantage was manifested at weaning time except in Brahman x Hereford calves. Subsequent gains of Herefords and the three Continental European crossbred groups were quite similar, however postweaning gains of the Brahman crosses excelled all breed groups, particularly from weaning to a year of age. This period coincided with the hottest season of the year from mid-summer to fall when forage quality was at its lowest. Results of the first phase of this study suggest that a producer could realize an increase of from 40 to 75 pounds at weaning and from 45 to 115 pounds at the long yearling weight by producing crossbred calves compared with producing straightbred Hereford calves.

In Phase II of the study, the heifers from Phase I were bred to Angus bulls to produce singlecross and three-breed cross calves over a 4-year period. No significant cow breed differences were detected for percent calf crop born or weaned. Large cow breed differences were observed, however, for cow weight, calf weaning weight, calf grade, pounds of calf weaned per cow weaning a calf and cash return per cow weaning a calf. All crossbred cow groups weaned heavier and higher scoring calves than the Hereford cows. The Brahman crosses ranked first for weaning weight and calf grade followed closely by the Simmental crosses with the Limousin and Maine-Anjou crosses ranked intermediate between the Brahman crosses and the Hereford cows. When cow weight and reproduction differences were removed, however, the Hereford cows were more efficient producers than the Limousin and Maine-Anjou crosses. Brahman and Simmental crosses were similar in efficiency per cow maintained in the herd and returned $27.99 and $32.27 more, respectively, per 1,000 pounds of cow maintained than the lowest ranking Maine-Anjou x Hereford cows. This study illustrates the importance of breed selection and utilization of crossbreeding for maximum return per cow.

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Appendix

The data in Phases I and II were statistically analyzed by least squares procedures using the General Linear Models procedure within the Statistical Analysis System (SAS Institute, Cary, NC). The mathematical model for Phase I data included the main effects of year, breed of sire and calf sex and all first order interactions. Cow age was used as a covariable for all traits, and weaning age was included as a covariable for weaning weight. Following weaning, the weighing dates, and hence ages, differed considerably for the first year compared with the second and third years of the study. Therefore the weights were adjusted by linear regression to a common age within year group (year one and years two and three) prior to analysis, and calf age was not included in the final models employed. The average yearling ages were 348 and 397 days and long yearling ages were 581 and 683 days for year one and years two and three, respectively.

Phase II data collected on the females produced in Phase I included 408 breeding records and 325 weaning records. For the cow reproduction data, the mathematical model included the effects of year, cow breed, year x cow breed interaction, and linear regression on cow age. For all other cow and calf traits analyzed in Phase II, the preceding model was used except that calf sex was included as a main effect, and calf age was included as a covariate when appropriate.

The analyses of variance are presented in Appendix Tables 1 through 3.

Appendix Table 1.—Analysis of Variance for Calf Growth Traits, Phase I

		Mean Squares			
Source	df	Birth wt.	Wean wt.	Yearling wt.	Long yearling wt.
Year (Y)	2	25.6	25,911**	23,468**	28,687**
Breed (B)	4	1,687.3**	36,277**	61,365**	95,082**
Calf Sex	1	2,606.9**	48,462**	66,876**	102,886**
YxB	8	18.5	2,405	6,467	10,061*
YxS	2	373.9**	2,819	5,102	6,247
BxS	4	125.4	7,998	18,783**	16,139*
b (cow age)	1	11.5	84,042**	50,702**	15,458
b (wean age)	1	—	30,268**	—	—
Error	210(209)[a]	87.0	3,610	4,665	5,039

[a]Error df = 209 for weaning weight only.
*P<.05, **P<.01.

Appendix Table 2.—Analysis of Variance for Percent Calf Crop Born and Weaned, Phase II

		Mean squares	
	df	Calf crop born	Calf crop weaned
Year	3	.5512**	.7787**
Cow breed	4	.0599	.0517
Year x Cow breed	12	.2783**	.4995**
b (cow age)	1	.0236	.0998
Error	387	.1181	.1532

*P<.05, **P=.01.

Appendix Table 3.—Analysis of Variance for Cow and Calf Traits, Phase II

		Mean squares							
Source	df	Birth date[b]	Birth wt.	Wean wt.	ADG April-July	Calf grade	Cow wt.	Lb. calf per cow	Dollar return per cow
Year (Y)	3	917	412**	97,551**	.821**	4.91	158,159**	.0167**	187,064**
Cow breed (B)	4	1,260	126	95,977**	.768**	17.40**	193,440**	.0215**	15,190**
YxB	12	1,220*	157	4,696*	.308**	1.69	8,743	.0035	1,374*
Calf sex	1	1,699	1,986**	115,908**	2.115**	2.46	1,573	.1237**	159,634
b(cow age)	1	1,478	2	1,830	.173	5.15*	265,401**	.0407**	2,891*
b(calf age)	1	—	—	450,399**	1.103**	60.47**	26,070	.3342**	90,502**
Error	(303)302[a]	672	94	2,555	.066	1.19	7,230	.0033	728

[a] Error df = 303 for birth date and birth wt. only.

[b] Based on Julian birth date, counting January 1 as day one.

$^*P<.05$, $^{**}P<.01$.

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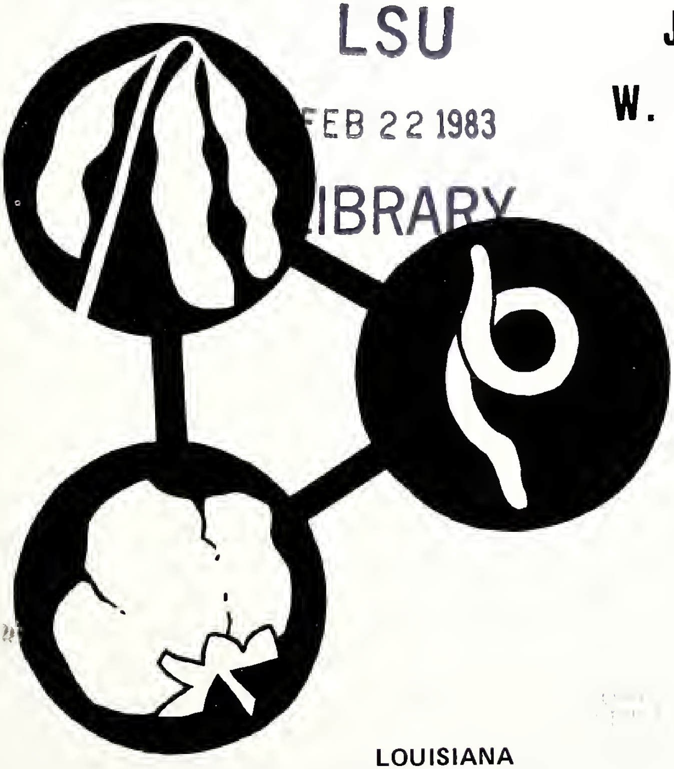

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Cotton-Soybean Rotation for Reniform Nematode Control

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Reniform nematodes have been reported in Avoyelles, Rapides, St. Landry, Orleans, Grant, East Baton Rouge, Morehouse, Richland, and several other parishes in Louisiana. Once a field is infested with this nematode, no known method will eliminate them. Populations can build to damaging proportions if susceptible cultivars are grown continuously in infested fields. Plant symptoms are not readily noticeable, and the nematode cannot be seen with the naked eye. Since reniform nematodes are quite resistant to soil drying (*4*)[5], they may be easily spread from field to field on farm equipment. Partial control can be obtained through proper use of nematicides, resistant cultivars and crop rotation. All commercially available cotton cultivars and most soybean cultivars are susceptible to this nematode. Resistant soybean cultivars commercially available to Louisiana producers are Forrest, Bedford, Pickett 71, and Centennial.

The objective of this study was to evaluate the effectiveness of cropping sequences, involving a reniform-resistant soybean cultivar in rotation with susceptible cotton and soybean cultivars, on degree of nematode control compared with continuous cropping of these cultivars with and without a nematicide.

Literature Review

The reniform nematode, *Rotylenchulus reniformis* Linford and Oliviera, was first reported as a plant parasite in 1940 (*11*). According to Linford and Oliviera, this nematode was probably observed by Hagan and Yap on cowpeas in 1931, but it was not investigated until 1936 (*11*). The common name "reniform nematode" was proposed to describe the usual kidney shape of the adult female.

The reniform nematode has a very wide host range, including the agronomically important families Graminae, Leguminosae, Malvaceae, and Solanaceae (*9, 19*). Only females are parasitic. Infective young females imbed themselves partially, sometimes entirely, in the root cortex of the cowpea (*11*). Birchfield (*1*) found that the young females initiated damage in cotton (*Gossypium hirsutum* L.) by extending the anterior portion of their bodies through the epidermis and cortical parenchyma to feed in phloem tissue. Young females began egg production 8-9 days after infection and completed their life in 17-23 days. Rebois (*14*) found that the life cycle was completed within 19 days on Lee and Hood soybeans [*Glycine max* L. (Merr)].

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[5] Italic numbers in parenthesis refer to Literature Cited, page 21.

Reniform nematode populations can increase greatly during the growing season. Jones et al. (*9*) made nematode counts at intervals from May 20 until August 25 and found that nematode numbers increased from 1,019 to 49,120 per 500 cm³ of soil in non-fumigated plots. Rebois (*15*) found reniform nematode infectivity on soybeans greatest when soil water content was maintained just below field capacity. Temperature affected nematode development and population growth rate (*14*). Rebois (*14*) reported that fecundity was highest on soybean roots maintained at 29.5°C.

The reniform nematode was first identified on cotton by G. Steiner, according to Smith (*18*). Neal (*12*) reported that a high incidence of fusarium wilt (*Fusarium oxysporium f. vasinfectum*, Atk., S. and H.) in a susceptible cotton variety was induced by reniform nematode infection. Smith and Taylor (*19*) observed a pronounced reniform nematode infection on roots of cotton and cowpeas in a fusarium wilt nursery at Baton Rouge. Khadr et al. (*10*) studied the reaction of 16 Egyptian cotton cultivars (*Gossypium barbadense* L.) to reniform nematode and fusarium wilt. They found that the reniform nematode increased wilt severity in highly and moderately susceptible cultivars and induced infection in wilt resistant cultivars. Jones et al. (*9*) reported that the nematode reproduced abundantly and caused a reduction in lint yield, a delay in maturity, a reduction in boil size, and in some years, a reduction in lint percent. Seed size, fiber length, fiber strength, and fiber fineness were not affected. Birchfield and Jones (*3*) attributed a yield reduction in cotton on 2,000-5,000 acres in Rapides and Avoyelles parishes in Louisiana to reniform nematode.

Yield increases in cotton from soil fumigation has varied with both variety and year. Jones et al. (*9*) obtained a 38 percent increase in lint yield in 1954, a 1.5 percent increase in 1955, and a 37.8 percent increase in 1956 from fumigation. Yield increases were greatest for cultivars highly susceptible to wilt. A 73 percent increase in lint yield resulted from fumigation for one cultivar.

Several workers have reported that reniform nematode parasitized soybeans (*2, 6, 7, 13, 17*). Williams and Birchfield (*20*) found that the pathogen caused root decay, unthrifty growth, and up to 10 percent yield reduction in susceptible soybean cultivars grown in Louisiana. In a greenhouse test, Rebois and Johnson (*16*) found that seed phosphorus decreased and potassium increased at low inoculum levels, but little change was noted in nitrogen content of the seed. Rebois et al. (*17*) reported that all soybean cultivars which were resistant to the reniform nematode also were resistant to the cyst nematode. They postulated a common source of resistance to both nematodes. Birchfield et al. (*5*) later showed that all cultivars resistant to the reniform nematode were not necessarily resistant to the soybean cyst nematode. Fontenot (*8*) studied the inheritance of resistance to the reniform nematode in the soybean cross, Forrest X Ransom. He found that susceptibility was dominant to resistance and that a small number of genes appeared to control resistance.

The reniform nematode apparently cannot reproduce on resistant soybean cultivars. Rebois et al. (*17*) did not find mature females or egg masses attached to roots of resistant cultivars. Resistant cultivars were penetrated by infective females, but the females soon died (*8*). The resistant cultivars Pickett and Dyer reduced a reniform nematode population from 10,000 to 500 per 500 cm^3 of soil over a 2.5 month period (*17*). Soybean cultivars varied in yield response and tolerance at low reniform nematode populations in greenhouse studies; however, at high initial populations (25,000 nemas per 3.8 liters soil) yield was consistently lower for both resistant and susceptible cultivars (*16*). Williams and Birchfield (*20*) found significantly lower reniform nematode populations in plots of resistant Pickett and Pickett 71 soybeans compared with plots of reniform susceptible cultivars. Soil fumigation reduced the reniform nematode population only slightly in Pickett and Pickett 71 soybean plots in comparison to plots where susceptible cultivars were grown. The susceptible cultivars did not yield as well with soil fumigation as resistant cultivars yielded without soil fumigation.

Procedure

Deltapine 45A cotton and Lee 68 and Pickett 71 soybeans were used in the study. Deltapine 45A is susceptible to the reniform nematode. Lee 68 (replaced by Lee 74) and Pickett 71 soybeans are grown commercially in Louisiana and are similar in morphology, disease resistance, and adaptability. However, Pickett 71 is resistant to the reniform nematode and races 1 and 3 of the soybean cyst nematode, whereas, Lee 68 is susceptible to both organisms.

The test was conducted at the Perkins Road Agronomy Farm in Baton Rouge for five years from 1972 through 1976. The soil, Olivier silt loam (Aquic Fragiudalf), was heavily and fairly uniformly infested with the reniform nematode. The field had been cropped continuously with cotton for several years prior to 1971. A reniform nematode susceptible soybean cultivar was grown on the entire test site in 1971 in an effort to improve on uniformity of nematode infestation prior to the initiation of the experiment.

Land preparation consisted of disking and bedding in the fall or early winter. In the spring, fertilizer was applied in row middles, old beds were disked, and new beds were formed over the fertilized areas. Before planting, 8.6 pounds per acre of DBCP, (1, 2-dibromo-3-chloropropane) (EC) was injected with 16 gallons of water into the center of the bed of the

Table 1.—Fertilizer date and rate, fumigation date, and planting date of a cotton-soybean rotation study conducted in reniform nematode infested Olivier silt loam, Baton Rouge.

Year	Date fertilizer applied[1]	Fertilization rate, lbs/acre	Soil fumigation date.	Planting date
1972[2]	April 21 June 14	0-80-80 60-0-0	April 21 May 16	May 5 May 17, 26
1973[3]	April 12	126-60-60	May 10	May 16
1974	April 9 July 2	0-60-60 60-0-0	May 14	May 17
1975	May 7 July 22	40-80-80 25-0-0	May 19	May 27
1976	May July 30	0-60-60 60-0-0	June 4	June 4

[1] Applied nitrogen to cotton by side dressing.

[2] Received 5. 2 inches of rainfall on May 7. Fumigated plots again and replanted cotton and soybean plots on May 17. The soybean plots were again replanted on May 26.

[3] Plots were unintentionally over-fertilized with nitrogen in 1973.

appropriate plots to a depth of about 8 inches. The injection knife was passed through all plots. The beds were reformed and knocked down to a height of about four inches immediately before planting. Ferilizer, fumigation, and planting dates are shown in Table 1.

Plots consisted of four rows, 40 inches wide and 50 feet long. Treatments were arranged in a randomized complete block design with six replications. Cotton was planted in excess and later thinned to four plants per foot of row.

The nematode population was monitored in 3 of 5 years at planting, and annually in August and late September or early October by taking a minimum of 10 soil cores from the center two rows of each plot. The samples were taken at a depth of 8 inches on the side of the row about 4 inches from the drill. Nematode counts were made using a technique previously described by Birchfield et al (*5*).

Weed control was maintained by using the preplant incorporated herbicide Treflan, cultivation, and hand hoeing. A 4- to 5-day spray schedule was used from bloom to mid-September for insect control in cotton. Soybeans were sprayed as needed for insect control.

Fourteen cropping sequences were established (Table 2).

Cotton

Yields were determined by mechanically harvesting the two center rows of each plot and are reported in pounds of lint per acre. Fiber properties were determined from a 50-boll sample hand picked from each treatment prior to first harvest. The samples were ginned on a laboratory saw gin and lint percent was computed. The following fiber properties were measured by the LSU Cotton Fiber Laboratory.

Micronaire—the fineness of the sample taken from ginned lint measured by the Fibronaire and expressed in standard micronaire units.

Span length—fiber length was measured on a Digital Fibrograph. The 2.5 percent span length is the length, in inches, on the test specimen spanned by 2.5 percent of the fibers scanned at the initial starting point. It closely approximated classer's staple. The 50 percent span length is the length, in inches, on the test specimen spanned by 50 percent of the fibers scanned at the initial starting point.

Fiber strength is the strength of a bundle of fibers measured on the Pressley Strength Tester, with the jaws holding the fiber bundle separated by an ⅛-inch spacer and expressed in grams-force per tex.

Table 2.—Cropping sequence by years of Deltapine 45A cotton and Lee 68 and Pickett 71 soybeans grown in reniform nematode infested Olivier silt loam, Baton Rouge.

1972	1973	1974	1975	1976
C[1]	C	C	C	C
C-F	C-F	C-F	C-F	C-F
L	L	L	L	L
L-F	L-F	L-F	L-F	L-F
P	P	P	P	P
P-F	P-F	P-F	P-F	P-F
C	L	C	P	C-F
C	P	C	P	C
L	C	L	L	C
P	C	P	P	C
P	P	C	C	L
P	P	L	C	L
L	P	L	L	C-F
P	L	P	P	L

[1] C = Deltapine 45A cotton, L = Lee 68 soybeans, P = Pickett 71 soybeans, and F = soil fumigated with 8.6 pounds per acre of DBCP.

Soybeans

Yields were determined from weight of seed harvested from the two center rows of each plot with a commercial combine. Yields are reported as bushels per acre of cleaned seed adjusted to 13 percent moisture.

Plant height was determined as the average length of mature plants from the ground to the top.

Lodging was recorded on a scale of 1 to 5 according to the following criteria:

1—almost all plants erect

2—either all plants leaning slightly, or a few plants down

3—either all plants leaning moderately, or 25 to 50 percent of the plants down
4—either all plants leaning considerately, or 50 to 80 percent of the plants down
5—all plants down

Percent protein and percent oil were determined from a composite of three replicates of 30 grams of seed from each treatment. Protein content was determined by the Kjeldahl procedure and oil content was determined by Nuclear Magnetic Resonance spectroscopy at the U.S. Regional Soybean Laboratory, Urbana, Illinois.

Statistical Analysis

Data from each year were analyzed separately and in a combined analysis across years. Treatment means were separated using Tukey's Honestly Significant Difference Test.

RESULTS

Effects of Cropping Sequence and Soil Fumigation on Nematode Populations

Initial reniform nematode populations were 1,200 nemas per 500 cm³ of soil in the non-fumigated plots and 200 nemas per 500 cm³ of soil in the fumigated plots (Table 3). Soil fumigation and cultivar resistance produced significant shifts in reniform nematode population levels at planting by the second year. Plots where 2 years of continuous cotton (11,140) and continuous Lee 68 soybeans (7,070) were grown without soil fumigation had significantly higher early season nematode numbers than fumigated plots (1,080 and 1,990, respectively) or plots where Pickett 71 soybeans were grown for one (avg. 705) or two (avg. 320) years. Nematode populations at planting in 1974 were lower in non-fumigated Pickett 71 plots than in fumigated Lee 68 soybean and fumigated cotton plots, although differences were not statistically significant.

Reniform nematode populations were considerably higher at planting in 1973 plots where Lee 68 soybeans or cotton had been grown in 1972 compared with plots containing Pickett 71 soybeans in 1972 (Table 3). Similarly, fewer reniform nematodes were present at planting in 1974 plots where Pickett 71 soybeans were grown in either 1973 or in both 1972 and 1973 than in plots where cotton or Lee 68 soybeans had been grown the previous year. Reniform nematode numbers were essentially equal at planting in fumigated and in non-fumigated plots where Pickett 71 soybeans were grown the previous year. Nematode population levels at planting in 1974 were similar in plots where cotton followed Lee 68 or Pickett 71

Table 3.—Infestation levels of reniform nematodes in soil at planting by years as affected by cropping sequences and fumigation treatment.

Cropping sequence[1]			Larvae/500 cm^3		
1972	1973	1974	1972[2]	1973	1974
C	C	C	1, 200	910	11,140
C-F	C-F	C-F	200	570	1,080
L	L	L	1, 200	940	7,070
L-F	L-F	L-F	200	210	1,990
P	P	P	1, 200	140	240
P-F	P-F	P-F	200	30	230
C	L	C	1, 200	910	4,000
C	P	C	1, 200	820	680
L	C	L	1, 200	490	8,590
P	C	P	1, 200	120	8,360
P	P	C	1, 200	50	470
P	P	L	1, 200	140	250
L	P	L	1, 200	610	730
P	L	P	1, 200	40	830
H.S.D.$_{.05}$			850	430	7,540

[1] C = Deltopine 45A, L = Lee 68 soybeans, P = Pickett 71 soybeans and F = soil fumigated with 8.6 pounds per acre of DBCP.

[2] Composited soil from plots with same treatment for nematode analyses.

soybeans (8,590 vs. 8,360). This was slightly higher than where Lee 68 soybeans had been grown for 2 years (7,070), considerably higher than where Lee 68 soybeans followed cotton (4,000), but lower than where cotton had been grown for 2 years (11,140).

Mid-season nematode populations fluctuated greatly from year to year in both cotton and Lee 68 soybean plots, irrespective of fumigation, but they were fairly consistent within treatments involving Pickett 71 soybeans (Table 4). The 5-year average mid-season nematode population was reduced significantly by soil fumigation in both cotton (from 11,530 to 3,470 per 500 cm^3 soil) and Lee 68 soybeans (9,820 to 1,460 per 500 cm^3 soil). Soil fumigation was effective in reducing the mid-summer nematode population in all 5 years of the test for the two susceptible hosts, but it had little effect on nematode population where the resistant soybean cultivar Pickett 71 was grown (260 vs. 130). Both susceptible hosts supported significantly more reniform nematodes than the resistant host at mid-summer. In fact, the reniform nematode population was higher at mid-season in fumigated plots of cotton and Lee 68 soybean than in non-fumigated Pickett 71 soybean plots in all years except 1972.

Cotton following 1 year of Lee 68 or Pickett 71 soybeans had a much higher mid-season nematode population than when Lee 68 followed cotton or Pickett 71 soybeans (Table 4). Regardless of the preceeding crop, Pickett 71 supported significantly fewer reniform larvae than Lee 68 or cotton, and was particularly effective in reducing the mid-season population of this nematode when grown for 2 or more successive years. In fact,

Table 4.—Infestation levels of reniform nematodes in soil at mid-season by years as affected by cropping sequences and fumigation treatment.

Cropping sequence[1]					Larvae/500 cm³				
1972	1973	1974	1975	1976	1972[2]	1973	1974	1975	1976
C	C	C	C	C	6,570	20,510	13,160	14,990	2,430
C-F	C-F	C-F	C-F	C-F	100	4,310	9,590	3,230	100
L	L	L	L	L	6,060	15,350	9,110	16,140	2,470
L-F	L-F	L-F	L-F	L-F	270	1,710	3,450	1,720	130
P	P	P	P	P	390	390	340	150	50
P-F	P-F	P-F	P-F	P-F	40	80	440	80	20
C	L	C	P	C-F	6,570	11,990	10,420	1,790	100
C	P	C	P	C	6,570	770	11,580	2,820	5,740
L	C	L	L	C	6,060	23,890	5,150	23,000	5,210
P	C	P	P	C	390	25,980	1,130	800	1,650
P	P	C	C	L	390	330	9,390	23,850	3,230
P	P	L	C	L	390	240	1,410	8,810	2,630
L	P	L	L	C-F	6,060	460	2,310	9,900	140
P	L	P	P	L	390	10,190	530	200	220
H.S.D.$_{.05}$					3,640	9,320	11,800	20,220	4,400

[1] C = Deltapine 45A cotton, L = Lee 68 soybeans, P = Pickett 71 soybeans, and F = soil fumigated with 8.6 pounds per acre of DBCP.

[2] Composited soil from plots with same treatment for nematode analyses.

non-fumigated cotton following 2 years of Pickett 71 had a similar reniform nematode population at mid-season as continuous cotton with soil fumigation. Likewise, non-fumigated Lee 68 following two years of Pickett 71 supported a similar mid-season nematode population as continuous Lee 68 with soil fumigation.

Nematode populations at harvest were extremely high when cotton and Lee 68 soybeans were grown continuously without fumigation (Table 5). Continuous Pickett 71 supported significantly lower reniform nematode populations than continuous cotton or Lee 68 soybeans. Fumigation significantly reduced nematode population levels at harvest in cotton and Lee 68 plots, but it had little effect where Pickett 71 was grown continuously. Although fumigation significantly reduced reniform nematode populations at harvest in cotton (10,410 vs. 4,340) and Lee 68 plots (6,800 vs. 2,160) as an average across years, there were fewer nematodes in non-fumigated Pickett 71 plots (340) than continuous cotton or Lee 68 plots with fumigation.

Cropping rotations involving cotton and Lee 68 soybeans in the current year tended to develop high reniform nematode populations at harvest (Table 5). Reniform nematode numbers were greatly reduced early in the growing season when Pickett 71 was the previous crop; however, population levels increased by harvest time when a susceptible host was grown. Two consecutive years of Pickett 71 further reduced the reniform population at harvest over that of 1 year of Pickett 71; however, nematode numbers increased to very high levels by crop maturity when a susceptible host was subsequently grown.

Table 5.—Infestation levels of reniform nematodes in soil at harvest by years as affected by cropping sequences and fumigation.

Cropping sequence[1]					Larvae/500 cm^3				
1972	1973	1974	1975	1976	1972[2]	1973	1974	1975	1976
C	C	C	C	C	13,150	17,240	12,210	2,160	7,290
C-F	C-F	C-F	C-F	C-F	630	9,990	9,360	1,000	700
L	L	L	L	L	10,720	8,790	8,130	2,010	4,370
L-F	L-F	L-F	L-F	L-F	130	3,130	6,510	760	290
P	P	P	P	P	550	480	450	70	160
P-F	P-F	P-F	P-F	P-F	350	160	230	30	80
C	L	C	P	C-F	13,150	9,650	13,330	160	590
C	P	C	P	C	13,150	870	9,910	700	4,200
L	C	L	L	C	10,720	18,570	12,290	2,150	3,970
P	C	P	P	C	550	12,860	850	100	3,530
P	P	C	C	L	550	370	13,160	3,020	2,820
P	P	L	C	L	550	270	4,660	2,680	2,600
L	P	L	L	C-F	10,720	380	5,180	1,470	1,750
P	L	P	P	L	550	8,070	1,020	150	1,910
H.S.D.$_{.05}$					7,460	9,910	9,060	2,210	3,720

[1] C = Deltapine 45A cotton, L = Lee 68 soybeans, P = Pickett 71 soybeans, and F = soil fumigated with 8.6 pounds per acre of DBCP.

[2] Composited soil from plots with same treatment for nematode analyses.

Large, mostly positive, changes occurred in reniform nematode population between planting and mid-season (Table 6). Population levels increased more in continuous cotton and continuous Lee 68 plots without soil fumigation than in plots with soil fumigation. Pickett 71 drastically reduced the initial nematode population but had little further effect on the population level. In the cropping sequences, all decreases in reniform population from planting until mid-season were in Pickett 71 plots, except for Lee 68 following cotton in 1974. Population increases were generally greater in plots containing cotton than in plots containing Lee 68 soybeans.

Nematode population shifts from planting to harvest were large in continuous cotton and Lee 68 plots irrespective of fumigation treatment, but they were small in continuous Pickett 71 plots (Table 7). Likewise, there were increases in population density from spring until fall in all treatments containing cotton or susceptible soybeans, except for fumigated Lee 68 in 1972. In 1974, cotton following 2 years of resistant soybeans had a significantly greater population change from planting until harvest than all other crop sequences involving Pickett 71 soybeans. The only large decrease in nematode population occurred in 1974 in the rotation Pickett 71-Deltapine 45A-Pickett 71, when 7,510 fewer nematodes were present at harvest than at planting.

The reniform nematode population change from mid-season until harvest for the various treatments varied greatly among years (Table 8). Continuous cropping treatments of susceptible hosts tended to have fewer nematodes at harvest than at mid-season, while the continuously cropped

Table 6.—Effect of cropping sequence and soil fumigation on the change in reniform nematode population from planting until mid-season.

Cropping sequence[1]			Population change		
1972	1973	1974	1972[2]	1973	1974
			Nematodes per 500 cm^3 of soil		
C	C	C	5,370	19,600	2,020
C-F	C-F	C-F	− 100	3,740	8,510
L	L	L	4,860	14,410	2,040
L-F	L-F	L-F	70	1,500	1,460
P	P	P	− 810	250	100
P-F	P-F	P-F	− 160	50	210
C	L	C	5,370	11,080	6,410
C	P	C	5,370	− 40	10,900
L	C	L	4,860	23,400	− 3,440
P	C	P	− 810	25,870	− 7,230
P	P	C	− 810	280	8,910
P	P	L	− 810	100	1,160
L	P	L	4,860	− 110	1,570
P	L	P	− 810	10,150	− 290
H.S.D.$_{.05}$			3,660	9,280	13,000

[1] C = Deltapine 45A cotton, L = Lee 68 soybeans, P = Pickett 71 soybeans, and F = soil fumigated with 8.6 pounds per acre of DBCP.

[2] Composited soil from plots with same treatment for nematode analyses.

Table 7.—Effect of cropping sequence and soil fumigation on the change in reniform nematode population from planting until harvest.

Cropping sequence[1]			Population change		
1972	1973	1974	1972[2]	1973	1974
			Nematodes per 500 cm^3 of soil		
C	C	C	11,950	16,330	1,070
C-F	C-F	C-F	430	9,420	8,280
L	L	L	9,520	7,840	1,060
L-F	L-F	L-F	− 70	2,920	4,520
P	P	P	− 650	340	210
P-F	P-F	P-F	150	130	10
C	L	C	11,950	8,740	9,330
C	P	C	11,950	50	9,230
L	C	L	9,520	18,080	4,700
P	C	P	− 650	12,740	− 7,510
P	P	C	− 650	320	12,690
P	P	L	− 650	130	4,410
L	P	L	9,520	− 230	4,450
P	L	P	− 650	8,030	190
H.S.D.$_{.05}$			7,460	9,850	10,580

[1] C = Deltapine 45A cotton, L = Lee 68 soybeans, P = Pickett 71 soybeans, and F = soil fumigated with 8.6 pounds per acre of DBCP.

[2] Composited soil from plots with same treatment for nematode analyses.

Pickett 71 tended to support small increases during this period. Significant shifts in nematode density between mid-season and harvest occurred among the various rotations during all years except 1974. Population changes from August to October appeared to be influenced more by environmental changes than cropping sequence.

Effect of Cropping Sequence and Soil Fumigation on Yield and Quality Measurements

Cotton

Fumigation increased lint yield of continuously grown cotton during 3 of the 5 years (Table 9). When averaged across years, fumigation increased lint yield from 581 to 694 pounds per acre, a highly significant difference of 113 pounds. The largest yield response to fumigation occurred in 1975 when lint yield was increased 66 percent or 383 pounds per acre over the non-treated check.

Crop rotation had no effect on lint yield in 1973 when yields were extremely low; all rotations produced similar or higher yields than continuous cotton during all other years of the study (Table 9). Lint yields were similar when non-fumigated cotton followed cotton or Lee 68 soybeans. But yields were higher when cotton followed 1 year of Pickett 71 compared with non-fumigated continuous cotton; they were appreciably higher when cotton followed 2 years of Pickett 71 compared with non-fumigated continuous cotton. In fact, cotton following 2 years of Pickett 71 had lint yields slightly higher than continuous cotton with fumigation. Cotton following 2 years of Pickett 71 yielded 839 pounds of lint per acre in 1976, which was 56 percent or 300 pounds per acre more than continuous cotton without fumigation and 7 percent or 55 pounds of lint per acre more than continuous cotton with soil fumigation. Cotton, in an alternate year rotation with Pickett 71, was significantly higher yielding (36 percent) in 1976 than continuous cotton without soil fumigation. Furthermore, there was a significant response to fumigation in 1976 when cotton followed cotton or Lee 68 soybeans but not when cotton followed Pickett 71. This is further evidence that 1 year of Pickett 71 had a measurable effect in suppressing this nematode.

Cropping sequence affected lint percent in only 2 years, 1972 and 1975 (Table 10). The effects were, for the most part, small and inconsistent.

Significant differences among treatments occurred for micronaire in 1974 and 1976 (Table 11). In 1974, Deltapine 45A produced lint with significantly lower micronaire values when following 1 and 2 years of Pickett 71 than when following Lee 68 or cotton, irrespective of fumigation treatment. In 1976, the micronaire value of fumigated continuous cotton

Table 8.—Effect of cropping sequences and soil fumigation on the change in reniform nematode population from mid-season until harvest.

Cropping sequence[1]					Population change				
1972	1973	1974	1975	1976	1972[2]	1973	1974	1975	1976
					Nematodes per 500 cm^3 of soil				
C	C	C	C	C	6,580	−3,270	−940	−12,830	−4,860
C-F	C-F	C-F	C-F	C-F	530	5,670	−230	−2,230	600
L	L	L	L	L	4,670	−6,570	−980	−14,130	1,900
L-F	L-F	L-F	L-F	L-F	−140	1,420	3,060	−970	160
P	P	P	P	P	160	100	110	−80	110
P-F	P-F	P-F	P-F	P-F	300	80	−210	−50	60
C	L	C	P	C-F	6,580	−2,340	2,920	−1,640	490
C	P	C	P	C	6,580	100	−1,680	−2,120	−1,540
L	C	L	L	C	4,670	−5,320	8,150	−20,850	−1,240
P	C	P	P	C	160	−13,130	−280	−970	−1,880
P	P	C	C	L	160	30	3,770	−20,830	−410
P	P	L	C	L	160	30	3,250	−6,120	−30
L	P	L	L	C-F	4,670	−90	2,880	−8,440	1,610
P	L	P	P	L	160	−2,120	490	−50	1,690
H.S.D.$_{.05}$					7,770	12,830	ns	15,780	5,630

[1] C = Deltapine 45A cotton, L = Lee 68 soybeans, P = Pickett 71 soybeans, and F = soil fumigated with 8.6 pounds per acre of DBCP.

[2] Composited soil from plots with same treatment for nematode analyses.

Table 9.—Cropping sequence effects on yield of Deltapine 45A cotton grown in reniform nematode infested soil.

Crop sequence[1]					Lint yield (lbs/acre)				
1972	1973	1974	1975	1976	1972	1973	1974	1975	1976
C	C	C	C	C	732	382	675	579	539
C-F	C-F	C-F	C-F	C-F	610	370	742	962	784
C	L	C	P	C-F	714	-	698	-	724
C	P	C	P	C	651	-	702	-	732
L	C	L	L	C	-	372	-	-	549
P	C	P	P	C	-	342	-	-	839
P	P	C	C	L	-	-	770	659	-
P	P	L	C	L	-	-	-	685	-
L	P	L	L	C-F	-	-	-	-	721
H.S.D.$_{.05}$					ns	ns	84	221	191

[1] C = Deltapine 45A cotton, L = Lee 68 soybeans, P = Pickett 71 soybeans, and F = soil fumigated with 8.6 pounds per acre of DBCP.

was not significantly different from that of continuous non-fumigated cotton or non-fumigated cotton following Lee 68 soybeans. However, these cropping sequences produced lint with generally higher micronaire values than when cotton followed Pickett 71 or when fumigated cotton followed Lee 68. This is interpreted to be the result of a combined response to nematode control and nitrogen accumulation resulting from soybean plant residue.

None of the cropping sequences had a significant effect on fiber length or fiber strength measurements.

Soybeans

Fumigation increased yield of continuous Lee 68 by an average of 2.5 bushels per acre (8 percent) but had no effect on continuous Pickett 71 soybean yield when averaged across years. Yield increases from fumigation were obtained during each year for Lee 68. Nevertheless, yields were consistently higher for non-fumigated Pickett 71 than for fumigated Lee 68 (Table 12). In the crop rotations, yields were somewhat higher for Lee 68 when following Pickett 71 than when following either Lee 68 or cotton, and in some cases, yields were significantly higher when following 2 years of Pickett 71 than when grown continuously without fumigation. In fact, Lee 68 produced 10 and 12 percent higher yields in 1974 and 1976, respectively, when following 2 years of Pickett 71 compared with continuous Lee 68 with soil fumigation, but in neither year was the difference significant.

Table 10.—Cropping sequence effects on lint percentage of Deltapine 45A cotton grown in reniform nematode infested soil.

Crop sequence[1]					Lint percent				
1972	1973	1974	1975	1976	1972	1973	1974	1975	1976
C	C	C	C	C	41.5	38.8	38.5	38.2	38.5
C-F	C-F	C-F	C-F	C-F	40.7	38.9	38.8	39.3	39.4
C	L	C	P	C-F	41.5	-	38.9	-	38.4
C	P	C	P	C	41.5	-	38.6	-	38.8
L	C	L	L	C	-	38.7	-	-	38.1
P	C	P	P	C	-	38.5	-	-	39.1
P	P	C	C	L	-	-	38.9	38.7	-
P	P	L	C	L	-	-	-	40.0	-
L	P	L	L	C-F	-	-	-	-	38.4
H.S.D.$_{.05}$					0.8	ns	ns	1.0	ns

[1] C = Deltapine 45A cotton, L = Lee 68 soybeans, P = Pickett 71 soybeans, and F = soil fumigated with 8.6 pounds per acre of DBCP.

Soil fumigation had no effect on soybean seed oil or protein content. However, Lee 68 had a significantly higher protein content than Pickett 71.

Small but significant differences were observed among cropping sequences for mature plant height (Table 13). Non-fumigated Lee 68 plants were shorter than fumigated Lee 68 plants during each year of the test, and they were significantly shorter than fumigated Lee 68 plants when averaged across years. The only significant differences in plant height among rotations occurred in 1974 when Pickett 71 followed Lee 68. These plants were significantly shorter than Pickett 71 plants grown continuously with fumigation.

Table 11.—Cropping sequence effects on micronaire of Deltapine 45A cotton grown in reniform nematode infested soil.

Crop sequence[1]					Micronaire (value)				
1972	1973	1974	1975	1976	1972	1973	1974	1975	1976
C	C	C	C	C	5.3	4.5	4.6	4.8	4.9
C-F	C-F	C-F	C-F	C-F	5.5	4.5	4.6	4.9	4.[illegible]
C	L	C	P	C-F	5.4	-	4.5	-	4.7
C	P	C	P	C	5.4	-	4.3	-	4.4
L	C	L	L	C	-	4.5	-	-	4.9
P	C	P	P	C	-	4.3	-	-	4.6
P	P	C	C	L	-	-	4.3	4.9	-
P	P	L	C	L	-	-	-	5.0	-
L	P	L	L	C-F	-	-	-	-	4.6
H.S.D.$_{.05}$					ns	ns	0.2	ns	0.3

[1] C = Deltapine 45A cotton, L = Lee 68 soybeans, P = Pickett 71 soybeans, and F = soil fumigated with 8.6 pounds per acre of DBCP.

Table 12.—Cropping sequence effects on yield of Lee 68 and Pickett 71 soybeans grown in reniform nematode infested soil.

Crop sequence[1]					Yield (bushels/acre)				
1972	1973	1974	1975	1976	1972	1973	1974	1975	1976
L	L	L	L	L	31.9	29.8	32.2	34.4	34.4
L-F	L-F	L-F	L-F	L-F	33.4	33.3	33.9	35.9	39.8
P	P	P	P	P	38.3	34.8	35.7	41.4	45.6
P-F	P-F	P-F	P-F	P-F	38.0	28.8	37.3	41.4	47.4
C	L	C	P	C-F	-	28.8	-	39.2	-
C	P	C	P	C	-	35.3	-	42.4	-
L	C	L	L	C	35.8	-	35.1	34.4	-
P	C	P	P	C	36.4	-	32.6	41.6	-
P	P	C	C	L	38.4	39.2	-	-	37.8
P	P	L	C	L	40.7	36.3	37.2	-	40.6
L	P	L	L	C-F	33.0	35.0	34.8	34.6	-
P	L	P	P	L	36.7	30.5	31.3	42.5	44.4
H.S.D.$_{.05}$					8.5	8.9	ns	7.9	7.0

[1] C = Deltapine 45A cotton, L = Lee 68 soybeans, P = Pickett 71 soybeans, and F = soil fumigated with 8.6 pounds per acre of DBCP.

Pickett 71 set pods significantly closer to the ground when following cotton than when grown continuously with fumigation in 1974, and Lee 68 set pods closer to the ground when following 2 years of cotton than when following 2 years of Pickett 71 in 1976 (Table 14). Fumigation had no effect on lower pod height of Lee 68 or Pickett 71 when grown continuously.

None of the cropping sequences had a significant effect on lodging or seed quality.

Table 13.—Cropping sequence effects on plant height of Lee 68 and Pickett 71 soybeans grown in reniform nematode infested soil.

Crop sequence[1]					Plant height (inches)		
1972	1973	1974	1975	1976	1974	1975	1976
L	L	L	L	L	26.0	35.8	33.8
[illegible]-F	L-F	L-F	L-F	L-F	28.3	36.5	37.7
P	P	P	P	P	26.8	38.5	37.7
P-F	P-F	P-F	P-F	P-F	27.2	36.8	36.5
C	L	C	P	C-F	-	35.8	-
C	P	C	P	C	-	35.5	-
L	C	L	L	C	25.5	33.2	-
P	C	P	P	C	26.2	38.2	-
P	P	C	C	L	-	-	35.0
P	P	L	C	L	37.3	-	34.7
L	P	L	L	C-F	30.0	35.8	-
P	L	P	P	L	23.2	36.5	38.1
H.S.D.$_{.05}$					3.9	ns	ns

[1] C = Deltapine 45A cotton, L = Lee 68 soybeons, P = Pickett 71 saybeons, ond F = sail fumigoted with 8.6 paunds per acre af DBCP.

Table 14.—Cropping sequence effects on lower pod height of Lee 68 and Pickett 71 soybeans grown in reniform nematode infested soil.

Crop sequence[1]					Height of lower pod (inches)		
1972	1973	1974	1975	1976	1974	1975	1976
L	L	L	L	L	5.0	4.5	5.0
L-F	L-F	L-F	L-F	L-F	5.2	4. 2	4.8
P	P	P	P	P	5.7	4.5	5.8
P-F	P-F	P-F	P-F	P-F	5.2	4.8	4.7
C	L	C	P	C-F	-	4.8	-
C	P	C	P	C	-	4.5	-
L	C	L	L	C	5.5	4.5	-
P	C	P	P	C	4.5	4.2	-
P	P	C	C	L	-	-	4.3
P	P	L	C	L	5.2	-	4.8
L	P	L	L	C-F	5.5	4.2	-
P	L	P	P	L	5.0	4.2	5.7
H.S.D.$_{.05}$					1.1	ns	1.2

[1] C = Deltapine 45A cotton, L = Lee 68 soybeons, P = Pickett 71 soybeans, and F = soil fumigoted with 8.6 pounds per acre of DBCP.

Discussion

Growing conditions varied considerably during the test period. Acceptable stands were obtained each year although the test had to be replanted in 1972 due to excessive rainfall immediately after planting. Soybean stands also were reduced on the fumigated plots in 1972, and plant growth was subnormal the entire year. Rainy weather in late August and early September in 1973 prevented timely applications of insecticide on the cotton. This resulted in a reduction in the top crop of bolls on all plots. Minor damage resulted from hurricane Carmen, September 9, 1974.

In 1975, excessive rainfall occurred in June, July, and August. Water remained on some plots for several days, resulting in stunted growth and minor weed problems. Therefore, two replications were not harvested for yield measurements. Ideal growing conditions occurred in 1976. Relatively drier soils may explain the low reniform nematode count at midseason in 1976 compared with other years. The average number of reniform nematodes was lower at harvest in 1976 than in all years except 1972.

A small number of reniform nematodes remained in the soil in continuous Pickett 71 soybean plots. Since reniform nematodes cannot reproduce on this cultivar (*17*), it is assumed that the nematodes reproduced on escaped weeds or were moved during tillage operations or by surface flooding. Reniform nematode numbers tended to decrease slightly in the resistant soybean plots during the test period and showed no tendency for new nematode biotypes or races to arise during this short period.

A resistant variety such as Pickett 71 reduces the nematodes population throughout the rooting zone; whereas, a fumigant reduces nematode numbers in a rather narrow band within the row. In mid-October of 1972, soil samples were taken 15 inches from the drill. Soil from Lee 68 plots had about 10 times more reniform nematodes than soil from Pickett 71 plots.

Conclusion

Since it was known that reniform nematodes could not reproduce on resistant soybean cultivars, it was theorized that certain rotation sequences involving resistant soybeans and susceptible hosts might eliminate the need for chemical control of this nematode. Data from this study did in fact demonstrate that growing a resistant soybean cultivar for 2 consecutive years would eliminate the need for fumigation for reniform nematode control when growing cotton or a susceptible soybean cultivar in the following year. Therefore, if a producer wanted to grow cotton or a susceptible soybean cultivar on a field infested with reniform nematodes he could eliminate the expense of fumigation for nematode control by following a rotation of 2 years of resistant soybeans and 1 year of cotton or susceptible soybeans. Although this study involved Pickett 71 as the reniform nematodes resistant soybean cultivar, it is assumed that other reniform-resistant soybean cultivars such as Forrest, Centennial, or Bedford would be equally as effective as Pickett 71 in suppressing populations of this nematode.

Summary

A 5-year rotation study, involving reniform nematode susceptible cotton and Lee 68 soybeans and reniform nematode resistant Pickett 71 soybeans, was conducted in reniform nematode infested Olivier silt loam soil at Baton Rouge. Treatments included 14 cropping sequences to permit the comparison of soil fumigation with selected cotton-soybean rotations on yields, quality factors, selected plant characters, and reniform nematode population changes.

A summary of the findings is listed below:

1. Soil fumigation with DBCP was effective in reducing reniform nematode numbers in soil of Deltapine 45A and Lee 68 plots at planting, mid-season, and harvest.
2. Deltapine 45A was a more suitable reniform nematode host than Lee 68.
3. Reniform nematode numbers remained low throughout the season in soil of continuously cropped Pickett 71, and fumigation reduced total numbers only slightly.
4. Pickett 71 following either crop was effective in greatly reducing the reniform population by mid-season and only 1 year of Pickett 71 reduced the reniform nematode population for the succeeding crop to a level at or below that obtained by soil fumigation. However, reniform nematode densities in plots of Deltapine 45A following 1 year of Pickett 71 increased by mid-season to the level present in plots of continuous cotton following Lee 68.
5. Soil in plots of Deltapine 45A and Lee 68 following 2 years of Pickett 71 had approximately the same reniform nematode populations at mid-season as when cropped continuously with fumigation.
6. One year of Pickett 71 was no better than 1 year of Lee 68 in reducing the reniform nematode population in Deltapine 45A at mid-season. However, 2 years of Pickett 71 was more effective than 2 years of Lee 68 in restricting the mid-season reniform nematode population in Deltapine 45A.
7. Soil fumigation significantly increased Deltapine 45A yields when averaged across years.
8. Deltapine 45A following 2 years of Pickett 71 yielded significantly more than continuous non-fumigated Deltapine 45A and slightly more than fumigated Deltapine 45A.
9. Cropping sequence and fumigation had little effect on lint percentage, micronaire, tensil strength, 2.5 percent span length, or 50 percent span length.
10. Fumigation increased yield of Lee 68 soybeans as an average of years, but had no effect on Pickett 71 yield.
11. Lee 68 following 2 years of Pickett 71 yielded significantly higher than Lee 68 grown continuously without fumigation, and slightly

more than Lee 68 grown continuously with fumigation.

12. Soil fumigation slightly increased mature plant height and lower pod height of Lee 68 but had no effect on Pickett 71 soybeans.
13. Cropping sequence and fumigation had little or no effect on seed protein content, oil content, lodging, seed quality, or seed size of the two soybean cultivars.

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Performance of Wheat Varieties In North Louisiana, 1980-82

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AND J. L. RABB[4]

Acreage in Louisiana devoted to wheat harvested for grain increased dramatically from 15,000 acres in 1978 to 500,000 acres in 1982 (Louisiana Crop Reporting Service official estimates). Wheat's suitability for multiple cropping with soybeans, grain sorghum, rice, and sugarcane has been primarily responsible for the increase in acreage that has elevated wheat to major crop status.

Screening wheat varieties through uniform statewide tests is essential to provide seed distributors and growers with information necessary for selecting types adapted to their areas. Breakdowns in varietal pest resistance, the release of new varieties, and the inconsistency in varietal response to environmental influences across years demand that variety testing be a continuous process. Since 1966, Louisiana Agricultural Experiment Station agronomists have been comparing the performance of wheat varieties in areas of Louisiana varying in climate and soil classification. Results of these annual evaluations have been published in the LSU Agronomy Research Report Series (Nos. 1, 7, 13, 19, 25, 30, 35, 40, 50, 55, 60, 65, 69, and 73) and in branch experiment station annual progress reports.

The comparative performances of wheat varieties grown at three north Louisiana locations from 1980 to 1982 are included in this publication. The absence of data for certain years from one central and several south Louisiana locations limits the scope of this bulletin to the performance of varieties in north Louisiana.

Materials and Methods

Tests were conducted at the Red River Valley Experiment Station at Bossier City on Upper Red River Alluvium soil, the Northeast Louisiana Experiment Station at St. Joseph on Mississippi River Alluvium, and the Northeast Louisiana Experiment Station at Winnsboro on Loessial Hills.

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Information concerning soil type, fertilization, planting and harvesting dates, and plot size at each test site is shown in Table 1. Recommended cultural and pest control practices were followed. Plots were seeded at the rate of 60 to 90 pounds per acre and harvested with a combine at all locations.

Entries selected for testing were either commercially available varieties or advanced experimental lines of the Soft Red Winter Wheat market class. Each year varieties were eliminated from or added to the tests according to seed availability and past performance. Data were recorded for grain yield, test-weight per bushel, mature plant height, lodging, disease reaction, and maturity. Grain yield was based on plot weights adjusted to 13 percent moisture. Yields are reported in bushels per acre, with 60 pounds per bushel. Test-weight-per-bushel determinations were made in accordance with USDA specifications as a measure of weight per unit volume. Mature plant height was determined as the average height of culms from the ground to the tip of the spikes. Lodging was rated subjectively using a scale of 1 to 5, with 1 = no plants lodged, 5 = severe lodging. Reactions to the major wheat diseases and maturity ratings for varieties that were included in all 3 years of the evaluations are shown in Table 2. A subjective rating scale was used to determine the relative susceptibility to disease pathogens. Date when approximately 50 percent of the spikes fully emerged from the boot and grain moisture at harvest were used to estimate maturity.

A randomized complete block experimental design with either four or five replications was used in the individual tests to evaluate varietal performance. Yield data from each year-location combination were statistically analyzed. Although the number of entries included in the tests varied each year, only 15 varieties were tested in all 3 years at each location. Yield data for these 15 varieties were analyzed in a combined analysis. Tukey's Honestly Significant Difference Test was used to determine if mean yield differences were statistically meaningful or due to chance. Mean yields at a given location or for a certain year that share a letter do not differ significantly at the 5 percent level of probability. Significantly different mean yields do not have letters in common. Coefficients of variation (C.V.) are given for each year-location combination (Tables 7, 8, and 9) to facilitate the comparison of yield data among locations.

Results

Environmental influences on grain yield resulting from differences in varietal performance, climatic conditions, and soil productivity, were clearly evident. The F tests from the combined analysis for yield indicated highly significant differences among years, locations, varieties, and the interactions among these factors (Table 3). As a result of these interactions,

Table 1.—General information for wheat variety test sites for each year

Location	Soil type[1]	Pounds per acre $N\text{-}P_2O_5\text{-}K_2O$ applied	Plot size (feet)	Planting date	Harvesting date
		1980			
Bossier City	Norwood sl c lm	50-0-0	5 × 75	10/18	6/13
St. Joseph	Sharkey c	35-0-0	12.5 × 40	11/20	6/05
Winnsboro	Grenada sl lm	60-60-60	5 × 55	10/26	6/06
		1981			
Bossier City	Norwood sl c lm	60-0-0	5 × 78	11/11	5/29
St. Joseph	Sharkey c	45-0-0	7 × 50	11/05-06	5/13-19
Winnsboro	Grenada sl lm	60-0-0	7.5 × 50	10/20	5/22
		1982			
Bossier City	Norwood sl c lm	60-0-0	4.6 × 70	11/03	6/04
St. Joseph	Sharkey c	40-0-0	7 × 35	11/05	5/18-19
Winnsboro	Grenada sl lm	68-0-0	7.5 × 50	10/27	5/18 & 6/03

[1] c = clay; sl lm = silt loam; sl c lm = silty clay loam.

Table 2.—Varietal resistance to major diseases and maturity ratings

Variety	Leaf rust resistance[1]	Septoria glume blotch resistance	Powdery mildew resistance	Maturity[2]
Arthur 71	Very poor (poor)	Poor	Poor	M-L
Coker 68-15	Poor (fair)	Poor	Very poor	M-L
Coker 747	Poor (fair)	Poor	Poor	M-L
Coker 762	Excellent	Fair	Good	M-L
Coker 797	Good	Very poor	Good	E
Coker 916	Excellent	Fair	Fair	M-L
Delta Queen	Poor (fair)	Poor	Good	M-L
Double Crop	Poor (fair)	Poor	Poor	M-E
Hart	Very poor	Poor	Poor	M-L
McNair 1003	Very poor (poor)	Poor	Good	M-E
McNair 1813	Poor	Poor	Good	E
Omega 78	Fair	Poor	Good	M-E
Rosen	Very poor (poor)	Poor	Very poor	M-E
Roy	Poor (fair)	Very poor	Very poor	M-L
Southern Belle	Poor (fair)	Very poor	Poor	E

[1] Leaf rust ratings are based on the most severe reactions observed in the state during 1980-82 and indicated the potential susceptibility of the cultivars. Ratings in parentheses are given for those varieties that displayed different reactions at the three north Louisiana locations during 1980-82.

[2] E = early; M-E = medium early; M-L = medium late. Ratings based on heading date and grain moisture at harvest.

Table 3.—Combined analysis of variance for yield of 15 wheat varieties grown at three north Louisiana locations, 1980-82

Source of variation[1]	df	MS	F
Total	582		
Year	2	23,477.9	74.52**
Location	2	5,751.3	18.26**
Year x location	4	6,003.2	19.06**
Error "a"	30	315.0	
Variety	14	1,257.8	25.46**
Variety x location	28	153.4	3.11**
Year x variety	28	568.4	11.51**
Year x variety x location	56	215.3	4.36**
Error "b"	418	49.4	

**Significant at the 1% level of probability.

statistical comparisons among mean yields involving more than one location were not made. However, this is of no consequence since state average yields are not meaningful to growers, most of whom farm in only one region of the state and are interested in variety adaptation for certain areas. More important is the relative performance of the wheat varieties at each location. For these comparisons, the average performance of the 15 varieties based on 3 years is shown for the separate locations in Tables 4, 5, and 6. Coker 916 was significantly superior to all varieties at Winnsboro and also was the highest yielding variety at Bossier City. Southern Belle had the largest mean yield at St. Joseph. Other consistently high-yielding entries

Table 4.—Agronomic performance of 15 wheat varieties grown on Norwood silty clay loam at Bossier City, 1980-82

Variety	Yield, bushels per acre[1]	Plant height, in.	Lodging[2]	Test-weight per bushel, pounds
Coker 916	64.5 a	37	1.7	58.0
Roy	60.7 ab	39	2.4	55.5
Southern Belle	56.2 abc	35	1.5	60.9
Coker 68-15	55.9 abc	38	2.2	59.6
Omega 78	55.3 abc	35	2.7	57.0
Coker 762	50.3 bcd	34	3.2	55.3
Coker 797	49.8 bcd	33	1.8	57.1
Rosen	48.6 cd	38	2.9	55.9
McNair 1003	47.3 cd	39	2.3	54.3
McNair 1813	46.1 cd	40	2.5	56.3
Coker 747	45.3 cd	36	2.5	57.6
Delta Queen	44.2 d	37	3.3	56.6
Hart	44.2 d	41	2.9	55.5
Double Crop	43.1 d	42	2.6	57.9
Arthur 71	41.0 d	40	2.9	58.1

[1] Means followed by a letter in common are not significantly different at the 5% level of probability according to Tukey's H.S.D. Test.

[2] Rated on a scale of 1 to 5, with 1 = none, 5 = severe.

Table 5.—Agronomic performance of 15 wheat varieties grown on Sharkey clay at St. Joseph, 1980-82

Variety	Yield, bushels per acre[1]	Plant height, in.	Lodging[2]	Test-weight per bushel, pounds
Southern Belle	54.0 a	36	1.1	58.6
Coker 916	50.9 a	36	1.4	56.9
Coker 68-15	*50.4 a	39	1.1	56.3
McNair 1003	49.6 a	39	1.9	50.8
Rasen	49.6 a	33	1.4	53.2
Coker 762	49.2 a	34	1.5	51.9
Coker 797	47.6 ab	34	1.1	55.2
Omega 78	47.6 ab	33	1.1	56.4
Ray	47.1 ab	38	1.4	52.9
Coker 747	*46.9 ab	35	1.4	56.9
Delta Queen	46.3 abc	37	1.8	53.8
McNair 1813	45.8 abc	37	1.6	55.8
Double Crop	40.0 bcd	39	1.9	59.7
Arthur 71	37.7 cd	38	1.8	55.2
Hart	32.0 d	37	1.5	53.6

[1] Means followed by a letter in common are not significantly different at the 5% level of probability according to Tukey's H.S.D. Test.

[2] Rated on a scale of 1 to 5, with 1 = none, 5 = severe.

*Average reflects one missing plot.

Table 6.—Agronomic performance of 15 wheat varieties grown on Grenada silt loam at Winnsboro, 1980-82

Variety	Yield, bushels per acre[1]	Plant height, in.	Lodging[2]	Test-weight per bushel, pounds
Coker 916	54.5 a	37	1.2	56.8
Southern Belle	45.0 b	35	1.2	58.1
Coker 68-15	42.5 bc	38	1.2	57.5
Coker 762	41.6 bc	35	1.7	50.2
Coker 747	41.3 bc	36	1.9	55.1
Rasen	41.1 bc	35	1.2	53.0
McNair 1813	40.2 bc	39	2.8	54.4
Ray	39.8 bc	39	1.9	51.0
Coker 797	39.4 bc	34	1.5	54.5
Double Crop	38.6 bc	39	1.5	59.6
Omega 78	38.5 bc	36	2.4	53.9
Delta Queen	37.5 c	34	2.4	52.7
McNair 1003	37.3 c	38	1.8	48.8
Arthur 71	28.6 d	39	2.8	56.2
Hart	26.5 d	37	1.0	55.0

[1] Means followed by a letter in common are not significantly different at the 5% level of probability according to Tukey's H.S.D. Test.

[2] Rated on a scale of 1 to 5, with 1 = none, 5 = severe.

were Coker 68-15 and 762, whereas Arthur 71 and Hart consistently had the lowest yields. Although Coker 68-15 and Southern Belle were among the top four wheats in yields at all test locations and displayed fair resistance to leaf rust during 1980-82, these varieties gave susceptible reactions to leaf rust elsewhere in the state during this period (Table 2, Footnote 1). It is reasonable to assume that the yield of these susceptible varieties could be severely reduced in years of high leaf rust severity at these northern locations.

In addition to grain yield differences, the varieties differed appreciably in plant height, lodging susceptibility, and test-weight per bushel (Tables 4, 5, and 6). Generally, taller varieties tend to lodge more, but two of the wheats most susceptible to lodging, Delta Queen and Coker 762, were among the shorter-statured ones. Lodging ratings reflect the degree of lodging that occurred under conditions of these studies and can be useful in selecting varieties most resistant to lodging. Even resistant varieties may lodge, however, when environmental conditions are conducive to extensive lodging. Test-weight per bushel varied greatly among the entries with Southern Belle and Double Crop exhibiting high test-weights at all sites. Coker 762 and particularly McNair 1003 consistently exhibited low test-weights.

In addition to the 15 varieties evaluated during all years, there were another 15 varieties included in the tests for 1 or more years. These were either newly released varieties that were tested for 1 or 2 years or varieties that were dropped from the testing program because of poor performance or seed unavailability. Tables 7 through 9 contain grain yield data by location for all the entries tested each year.

Table 7.—Mean yield of wheat varieties grown on Norwood silty clay loam at Bossier City, 1980-82

Variety	Year		
	1980	1981	1982
	Bushels per acre[1]		
Coker 916	66.2 a	51.7 ab	75.6 a
Coker 68-15	57.5 ab	55.5 ab	54.7 abcdef
Ray	48.4 bc	62.0 a	71.7 a
Omega 78	45.7 bcd	56.4 ab	63.7 abc
Southern Belle	44.1 bcde	55.3 ab	69.1 a
Coker 747	42.8 bcdef	49.7 b	43.3 bcdefg
Coker 797	38.5 cdefg	51.4 ab	59.6 abcde
Beau	38.3 cdefg	49.5 b	—
Coker 762	36.4 cdefg	52.3 ab	62.2 abc
Hart	35.4 cdefg	61.2 ab	35.9 efg
Sullivan	32.1 cdefg	—	—
Arthur 71	31.2 defg	55.1 ab	36.8 defg
McNair 1813	31.0 defg	54.0 ab	53.2 abcdef
Rasen	28.8 efg	57.3 ab	59.7 abcde
Oasis	26.9 fg	—	—
Abe	26.3 fg	—	—
Delta Queen	22.6 g	51.2 ab	58.9 abcde
McNair 1003	22.6 g	58.8 ab	60.6 abcde
Double Crop	21.9 g	51.4 ab	55.9 abcde
Terral 800-22	—	55.7 ab	67.1 ab
Titan	—	52.3 ab	—
Auburn	—	—	68.8 a
Terral 81-17	—	—	67.4 ab
Florida 301	—	—	61.6 abcd
Hunter	—	—	59.9 abcde
Caldwell	—	—	55.2 abcdef
Wheeler	—	—	52.5 abcdefg
Pike	—	—	39.3 cdefg
Tyler	—	—	30.6 fg
Massey	—	—	28.2 g
C.V.(%)	19.4	9.5	18.7

[1] Means followed by a letter in common are not significantly different at the 5% level of probability according to Tukey's H.S.D. Test. Comparisons are valid only between yields in the same year.

Table 8.—Mean yield of wheat varieties grown on Sharkey clay at St. Joseph, 1980-82

Variety	Year		
	1980	1981	1982
	Bushels per acre[1]		
Ray	29.7 a	54.5 bcde	57.2 abcd
Coker 762	27.0 ab	55.1 bcde	65.4 a
Coker 68-15	26.3 ab	67.2 abc	*60.2 abc
Delta Queen	25.9 abc	51.7 cde	61.3 ab
Beau	25.8 abc	58.1 bcde	—
Southern Belle	25.3 abc	79.6 a	57.2 abcd
Coker 747	25.3 abc	60.7 abcd	*57.4 abcd
Arthur 71	25.2 abc	46.9 de	40.9 d
Sullivan	23.7 abcd	—	—
Abe	23.6 abcd	—	—
McNair 1003	22.7 abcd	69.9 abc	56.3 abcd
Coker 916	22.6 abcd	72.1 ab	57.9 abcd
McNair 1813	22.2 abcd	66.4 abcd	48.8 abcd
Rasen	20.2 abcd	68.9 abc	59.7 abc
Hart	19.3 bcd	56.5 bcde	20.2 e
Double Crop	16.8 bcd	55.7 bcde	47.5 bcd
Coker 797	15.7 cd	65.7 abcd	61.3 ab
Omega 78	15.6 cd	70.1 abc	57.0 abcd
Oasis	13.4 d	—	—
Titan	—	37.9 e	—
Hunter	—	—	62.5 ab
Terral 800-22	—	—	60.8 ab
Terral 81-17	—	—	58.1 abcd
Florida 301	—	—	57.3 abcd
Wheeler	—	—	47.6 bcd
Massey	—	—	46.2 bcd
Caldwell	—	—	45.2 bcd
Pike	—	—	42.9 cd
C.V. (%)	17.5	12.5	12.2

[1] Means followed by a letter in common are not significantly different at the 5% level of probability according to Tukey's H.S.D. Test. Comparisons are valid only between yields in the same year.

*Average reflects one missing plot.

Table 9.—Mean yield of wheat varieties grown on Grenada silt loam at Winnsboro, 1980-82

Variety	Year		
	1980	1981	1982
	Bushels per acre[1]		
Coker 916	64.8 a	42.0 abcd	56.8 a
Hart	46.6 b	26.1 f	6.8 h
Ray	44.4 b	38.6 bcde	36.5 bcde
Southern Belle	41.6 bc	52.7 a	40.7 bc
Rosen	41.3 bc	46.9 abc	35.0 bcdefg
Coker 747	41.1 bc	43.6 abcd	39.2 bcd
Coker 68-15	39.1 bcd	43.7 abcd	44.7 abc
Double Crop	39.0 bcd	37.6 cdef	39.3 bcd
Beau	36.8 bcde	29.9 ef	—
McNair 1813	35.6 bcde	50.4 ab	34.5 cdefg
Delta Queen	30.4 cdef	44.3 abcd	37.8 bcde
Coker 797	30.3 cdef	52.9 a	35.1 bcdef
Coker 762	30.1 cdef	44.8 abc	50.0 ab
Oasis	29.5 def	—	—
Sullivan	29.2 def	—	—
Arthur 71	28.8 def	32.3 def	24.8 defg
Omega 78	25.8 ef	44.8 abc	44.9 abc
McNair 1003	25.7 ef	52.4 a	33.7 cdefg
Abe	23.3 f	—	—
Titan	—	36.8 cdef	—
Hunter	—	—	46.4 abc
Florida 301	—	—	44.1 abc
Caldwell	—	—	39.8 bcd
Wheeler	—	—	39.8 bcd
Terral 81-17	—	—	37.6 bcde
Auburn	—	—	33.9 cdefg
Massey	—	—	22.6 efg
Terral 800-22	—	—	21.0 fgh
Tyler	—	—	20.7 fgh
Pike	—	—	19.8 gh
C.V. (%)	12.2	10.9	16.0

[1] Means followed by a letter in common are not significantly different at the 5% level of probability according to Tukey's H.S.D. Test. Comparisons are valid only between yields in the same year.

Recommendations

The statewide variety evaluation program provides results that serve as a basis for recommending varieties. However, only varieties that have been included in the testing program for a minimum of 3 years are eligible for recommendation. A list of recommended varieties is compiled each year by the Small Grain Variety Review Committee and is made available through the Louisiana Cooperative Extension Service. Growers should exercise caution when selecting varieties that have not been adequately evaluated for their particular location. Except for Arthur 71, Double Crop, and Hart, all of the 15 varieties evaluated during all 3 years of the study were recommended for production in 1982-83 at one or more locations in the state.

Recommended Varieties

Northwest Louisiana[5]—Coker 762, Coker 797, Coker 916, Omega 78, Roy, and Southern Belle.

Northeast Louisiana (alluvial soils)[6]—Coker 68-15, Coker 747, Coker 762, Coker 797, Coker 916, Delta Queen, McNair 1003, Omega 78, Rosen, Roy, and Southern Belle.

Northeast Louisiana (ridge soils)[7]—Coker 68-15, Coker 747, Coker 762, Coker 916, McNair 1813, Rosen, Roy, and Southern Belle.

Central Louisiana[8]—Coker 747, Coker 762, Coker 797, Delta Queen, Omega 78, Rosen, and Southern Belle.

South Louisiana[9]—Coker 762, Coker 797, Delta Queen, McNair 1003, McNair 1813, Omega 78, and Southern Belle.

Coker 916 is a promising variety for central and south Louisiana, Roy is a promising variety for central Louisiana, and Terral 800-22 is a promising variety for northwest Louisiana.

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[5] Data collected at Red River Valley Experiment Station, Bossier City.

[6] Data collected at Northeast Louisiana Experiment Station, St. Joseph.

[7] Data collected at Northeast Louisiana Experiment Station, Winnsboro.

[8] Data collected at Dean Lee Agricultural Center, Alexandria.

[9] Data collected at Perkins Road Agronomy Farm, Baton Rouge; Rice Experiment Station, Crowley, and Iberia Livestock Experiment Station, Jeanerette.

Table 10.—Originating agencies for the wheat varieties included in the 1980-82 performance tests

Variety	Originating agency
Abe, Auburn, Arthur 71, Beau, Caldwell, Oasis, Sullivan	Indiana Agricultural Experiment Station
Coker 68-15, 747, 762, 797, 916	Coker's Pedigreed Seed Company, South Carolina
Delta Queen, Southern Belle, Hunter	North American Plant Breeders, Indiana
Double Crop, Rosen	Arkansas Agricultural Experiment Station
Florida 301	Florida Agricultural Experiment Station
Hart, Pike	Missouri Agricultural Experiment Station
McNair 1003, 1813	Northrup King Seed Company, North Carolina
Massey, Tyler, Wheeler	Virginia Agricultural Experiment Station
Omega 78	Georgia Agricultural Experiment Station
Ray	North Carolina Agricultural Research Service
Terral 800-22, 81-17	Terral-Norris Seed Company, Inc., Louisiana
Titan	Ohio Agricultural Experiment Station

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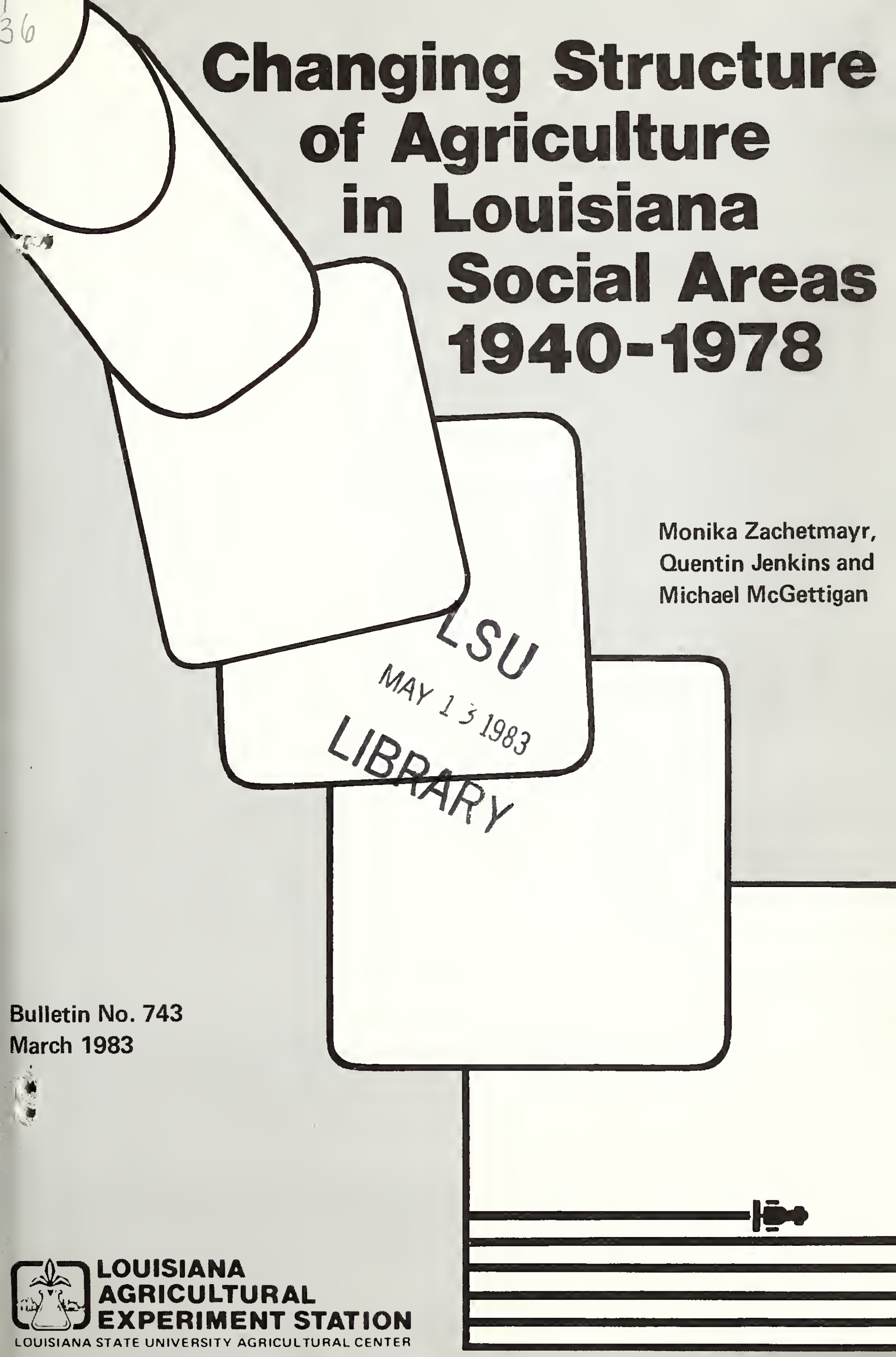
Changing Structure of Agriculture in Louisiana Social Areas 1940-1978



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The Louisiana Agricultural Experiment Station follows a nondiscriminatory policy in programs and employment.

Changing Structure of Agriculture in Louisiana Social Areas, 1940-1978

MONIKA ZECHETMAYR, QUENTIN JENKINS,
AND MICHAEL MCGETTIGAN[1]

This bulletin is part of a research project undertaken by the Department of Rural Sociology with the support of the LSU Agricultural Experiment Station. It was prepared as a service to the people of Louisiana to provide information regarding socio-agricultural change in the state from 1940 to 1978. It is hoped that documentation of these changes will provide a basis for comparisons between various socio-cultural areas in the state and other regions of the United States.

All statistics presented here were compiled from the *Census of Agriculture* for selected years 1940 to 1978, and the 1978 data were drawn from the 1978 *Census of Agriculture (Preliminary Report)* for each parish. Due to changes in the definition of "farm," these figures are not directly comparable over time; however, general trends can be discerned. (See Appendix A for elaboration on the problem of definition changes.) Consequently, when considering the variables here presented over time, the percentage figures stand merely as general estimates.

Following the clustering of Louisiana's 64 parishes (counties) into rural social areas as delineated by Bertrand (1955), we present data focusing on the following variables: (1) number of farms, (2) number of farms by size, (3) average size of farms, (4) the value of farm lands and buildings, and (5) tenure characteristics. The selection of these variables was based on their theoretical interrelatedness and their being indicative of trends in the changing structure of agriculture in Louisiana.

Louisiana Social Areas

Rather than dividing Louisiana into regions directly corresponding to types of farming areas (see Fielder, 1980:1), we have elected to partition the state into "rural social areas." In developing the delineation of these social areas, Bertrand (1955) used seven factors as significant measures of homogeneity: (1) school expenditures per parish per student, (2) proportion of land in farms, (3) age index, (4) race index, (5) the level of living of the rural non-farm population, (6) the level of living of the rural farm population, and (7) the fertility ratio of the rural farm population. As Bertrand points out, "There is a close relationship between type-farming and the areas delineated as rural social areas" (1955:32). Although Bertrand discerned 10 social areas we have here reduced the number to nine by combining two non-contiguous areas into one—the North Central Cut-Over area and the West Central Cut-Over Area, which are virtually identical in sociocultural characteristics. The nine rural social areas as adapted for this analysis are as follows (Figure 1):

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Area I—The Red River Delta Area: Bossier, Caddo, De Soto, Natchitoches, Rapides, and Red River parishes, extending from the northwestern corner to the central part of the state.

Area II—The North Louisiana Uplands: Bienville, Claiborne, Lincoln, Ouachita, Union, and Webster parishes, which are largely located in hilly terrain.

Area III—The Mississippi Delta Area: Catahoula, Concordia, East Carroll, East Feliciana, Franklin, Madison, Morehouse, Pointe Coupee, Richland, Tensas, West Carroll, and West Feliciana parishes. This area is historically associated with large plantation cotton production.

Area IV—North Central and West Central Cut-Over Area: Beauregard, Caldwell, Grant, Jackson, La Salle, Sabine, Vernon, and Winn parishes.

Area V—The Southwest Rice Area: Acadia, Allen, Calcasieu, Cameron, Jefferson Davis, and Vermilion parishes.

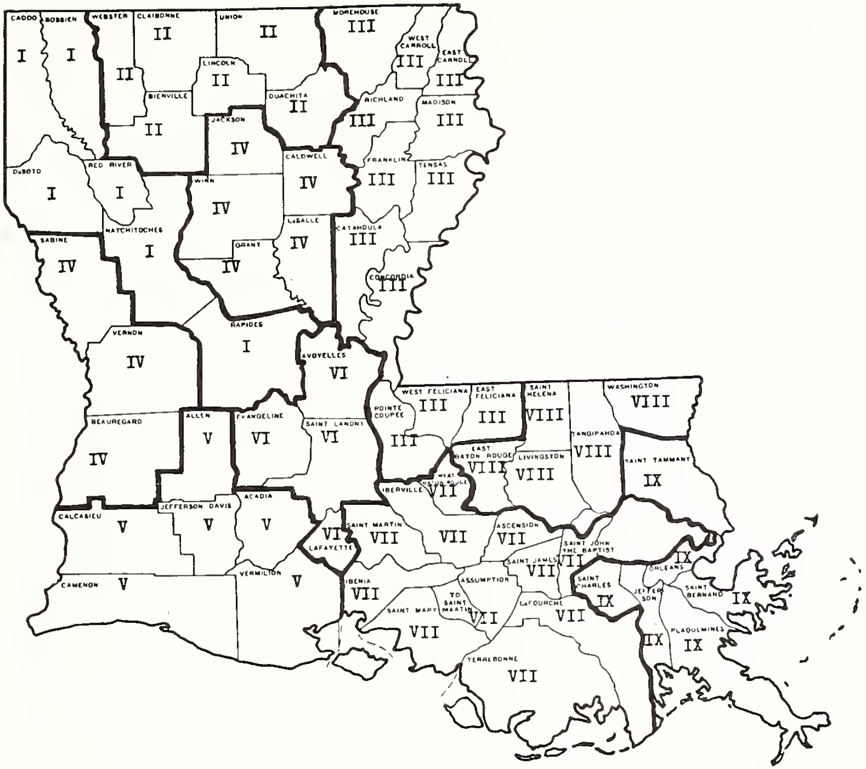
Area VI—The South Central Mixed Farming Area: Avoyelles, Evangeline, Lafayette, and St. Landry parishes. This is a densely populated intensified farming area.

Area VII—The Sugar Bowl: Ascension, Assumption, Iberia, Iberville, Lafourche, St. James, St. John, St. Martin, St. Mary, Terrebonne, and West Baton Rouge parishes, all of which are part of French south Louisiana.

Area VIII—The Florida Parishes: East Baton Rouge, Livingston, St. Helena, Tangipahoa, and Washington parishes.

Area IX—The New Orleans Truck and Fruit Area: Jefferson, Plaquemines, St. Bernard, St. Charles, and St. Tammany parishes. Data for Orleans Parish are included only in Table 1 as this parish is no longer rural.

As each of the five previously listed variables is discussed in the following pages, tables are provided. Several tables are also to be found in Appendix B which provide greater detail at both the individual parish level and social area level.



I. Red River Delta Area
II. North Louisiana Uplands Area
III. Mississippi Delta Area
IV. North and West Central Cut-Over Area
V. Southwest Rice Area
VI. South Central Mixed Farming Area
VII. The Sugar Bowl Area
VIII. The Florida Parishes
IX. New Orleans Truck and Fruit Area

Figure 1.—Louisiana social areas

Number of Farms

Declining farm numbers are not unique to Louisiana. As consistantly pointed out in the literature since about 1940, the number of farms in the United States has declined rapidly (Merrill, 1978) and continues to decline (Heady, 1981) irrespective of changing farm definitions.

The statewide number of farms in 1940, approximately 150,007, declined to a 1978 total of 31,389, a 79 percent reduction in number of farms (Table 1). (See Appendix B Table 1-B for parish figures.) The greatest reductions in numbers of farms has taken place in social areas I through IV

Table 1.—Number and percent of farms in Louisiana by social areas for selected years 1940-1978

Area	1940	1950	1959	1969	1974	1978	Percent reduction of 1978 figures from 1940 figures
I. Red River Delta	23,129 (15.4)	17,330 (14.0)	9,307 (12.2)	4,660 (11.0)	3,958 (11.9)	3,659 (11.6)	84.2
II. North Louisiana Uplands	18,215 (12.1)	12,087 (9.7)	6,421 (8.6)	3,183 (7.5)	2,571 (7.7)	2,513 (8.0)	86.2
III. Mississippi Delta	35,616 (23.7)	27,153 (21.9)	14,261 (19.2)	8,732 (20.6)	6,929 (20.8)	6,401 (20.4)	82.0
IV. North And West Central Cut-Over Area	12,792 (8.5)	11,420 (9.2)	7,232 (9.7)	3,382 (8.0)	2,958 (8.9)	3,023 (9.6)	76.4
V. Southwest Rice Area	12,914 (8.6)	11,862 (9.6)	7,836 (10.5)	5,773 (13.6)	4,515 (13.6)	4,556 (14.5)	64.7
VI. South Central Mixed Farming Area	21,144 (14.1)	18,801 (15.1)	13,105 (17.6)	7,844 (18.6)	5,362 (16.1)	4,579 (14.6)	78.4
VII. Sugar Bowl Area	9,997 (6.7)	9,032 (7.3)	5,882 (7.9)	3,423 (8.1)	2,508 (7.5)	2,389 (7.6)	76.1
VIII. Florida Parishes	13,506 (9.0)	13,652 (11.0)	8,919 (12.0)	4,483 (10.6)	3,754 (11.3)	3,482 (11.1)	74.2
IX. New Orleans Truck And Fruit Area	2,694 (1.8)	2,844 (2.3)	1,475 (2.0)	789 (1.9)	678 (2.0)	787 (2.5)	70.8
Totals	150,007	124,181	74,438	42,269	33,233	31,389	
Percent*	(99.9)	(100.1)	(99.7)	(99.9)	(99.8)	(99.9)	

*Deviations from 100 percent due to rounding error.

Compiled from the Census of Agriculture for the designated years.

(North Louisiana) ranging in magnitude from an 86.2 percent reduction in Area II (North Louisiana Uplands) to a 76.4 percent reduction for Area IV (North and West Central Cut-Over Area). In 1940, Area II (North Louisiana Uplands) encompassed 12.1 percent of the farms in the state, while in 1978 this number had decreased to 8 percent. Although all nine social areas display reductions in the number of farms from 1940 to 1978, social areas V through IX (South Louisiana) have decreases of lesser magnitude ranging from 78.4 percent in number of farms in Area VI (South Central Mixed Farming Area) to a 64.7 percent reduction in Area V (Southwest Rice Area). Despite the reduction in number of farms in Area V, the area's percentage of farms in the state as a whole increased from a 1940 low of 8.6 percent to the 1978 rate of 14.5 percent.

The factor Merrill (1978: 250) suggests to have been most influential in this change in rural areas is the post World War II economy which resulted in the relocating of many people from rural agricultural areas to industrializing urban areas. Merrill further states:

> Since the war, while the United States has grown by 55 million people, 3 million farms have disappeared in the technological revolution that is still sweeping agriculture. More than one million people have abandoned rural lands and towns for the cities so that 75% of our people are now crowded onto less than 2% of the land.

This "technological revolution" in agriculture has been facilitated, according to Friedland (1978:256), through the expenditure of millions of dollars in "the development and dispersal of agricultural technology through the complex network of the 'agricultural establishment' " including "the United States Department of Agriculture, the land-grant complex of universities, the agricultural experiment stations, and agricultural extension programs." The push for increased efficiency in farming practices in terms of the introduction of costly technological devices has, according to Friedland, "continually created a push out of agriculture and rural society of those farmers who have become defined as 'marginal' at any given period of time." Many farmers in Louisiana and elsewhere in the United States were unable to compete due to the increase in capital expenditure which "has been substituted for labor in production to take advantage of modern technological advances" (Reiling and Guedry, 1977: 12). Associated with the decline in the number of farms is change in size of those farms remaining.

Size of Farms

Through the years farms in the United States as well as Louisiana, while decreasing in number, simultaneously tended to increase in size. This trend in Louisiana has been especially pronounced since 1940 in the rice areas of the state where soil and climatic conditions as well as increasing demand for rice in both national and international markets favorably influenced mechanization and the development of larger farms. Cotton was second in mechanization, followed by family-type farming units of the mixed farming group (Bertrand, 1951: 9-10)

The larger farms are able to employ both machinery and labor to maintain or further increase their net income, due to a higher market capacity resulting from increases in harvested products (Constandse, *et al.* 1968: 25). This in turn can lead to increasing interest in the purchase of more land to further maximize production as well as minimize taxes. Smaller farms, or those becoming smaller, according to Constandse, *et al.* (1968:22) "were generally those on which older people remained," with tendencies toward selling or renting their lands as they grow older. "This tendency was especially pronounced in the dairy areas" of Louisiana.

There are trends of increasing farm size in all nine social areas (Table 2). See Appendix B Table 2-B for parish figures. The increases from 1940 to 1978 ranged from a low of approximately 143 percent average size of farm increase in Areas II (North Louisiana Uplands) and VIII (The Florida Parishes) to a high of a 633 percent average farm size increase in Area III (Mississippi Delta Area). Area II is noted for having family size owner-operated farms with many of the farmers being part-time operators. Supplementary farm enterprises include beef cattle, dairying, and poultry production, and crops produced include cotton, some fruit, and various truck crops.

Similarly, Area VIII is noted as a dairy area which "also has considerable acreage of strawberries and vegetable crops"(Bertrand, 1955). On the other hand, Area III, which had the largest increase in average farm size between 1940 and 1978, is a region of highly commercial farms focusing on the production of cotton, beef cattle, hay, and soybeans. In 1978 the average farm size in this area (484 acres) was somewhat larger than that of any other social area.

The second and third largest average sized farms in 1978 are respectively in Area V (Southwest Rice Area), 453 acres, and Area VII (The Sugar Bowl Area), 436 acres. These two areas also held (although in reverse order of magnitude) first and second place in the largest average size of farms in 1940.

In order to grasp more clearly the relationship between the diminishing number of farms and the increasing average size of farms, we will now consider the changing numbers of farms by size over the years 1940 to 1978.

Number of Farms By Size

All nine social areas show a substantial decrease in numbers of farms of 179 or fewer acres (Table 3). These decreases range from a high of 30,811 farms in Area III (Mississippi Delta) to a low of 1,909 farms in Area IX

Table 2.—Average size of farms in acres by social areas for selected years 1940-1978

Area		1940	1950	1959	1969	1974	1978	Change in Mean Acres 1940-1978	Percent Change 1940-1978
I.	Red River Delta	66	91	168	292	307	332	+266	+403%
II.	North Louisiana Uplands	82	102	131	186	183	199	+117	+143%
III.	Mississippi Delta	66	110	204	378	452	484	+418	+633%
IV.	North And West Central Cut Over Area	63	70	92	141	163	161	+ 98	+156%
V.	Southwest Rice Area	100	172	317	400	475	453	+353	+353%
VI.	South Central Mixed	37	48	70	98	167	210	+173	+468%
VII.	Sugar Bowl Area	139	184	258	374	435	436	+297	+214%
VIII.	Florida Parishes	59	62	83	126	140	143	+ 84	+142%
IX.	New Orleans Truck	69	121	198	268	406	302	+233	+338%

Compiled from the *Census of Agriculture* for the designated years.

Table 3.—Number of farms by size and social areas for selected years 1940-1978

Area I Red River Delta

	(1940)	(1950)	(1959)	(1969)	(1974)	(1978)	change in numbers 1940-1978
1-49 acres	17,167	11,822	5,167	1,451	1,004	1,085	-16,082
50-179 acres	4,897	4,031	2,608	1,656	1,507	1,306	-3,591
180-999 acres	1,107	1,261	1,241	1,259	1,032	991	-116
1000 and larger	160	214	246	294	295	277	+117

Area II North Louisiana Uplands

	(1940)	(1950)	(1959)	(1969)	(1974)	(1978)	change in numbers 1940-1978
1-49 acres	9,465	5,640	2,762	893	677	693	-8,772
50-179 acres	7,310	4,957	2,499	1,432	1,190	1,059	-6,251
180-999 acres	1,567	1,467	1,066	818	654	699	-868
1000 and larger	50	88	82	70	50	62	+12

Area III Mississippi Delta

	(1940)	(1950)	(1959)	(1969)	(1974)	(1978)	change in numbers 1940-1978
1-49 acres	30,001	27,373	7,309	2,547	1,727	1,440	-28,561
50-179 acres	4,172	5,849	4,631	3,131	2,368	1,922	-2,250
180-999 acres	1,122	1,501	1,927	2,463	2,238	2,325	+1,203
1000 and larger	310	386	337	591	596	704	+394

Area IV North and West Central Cut-Over Area

	(1940)	(1950)	(1959)	(1969)	(1974)	(1978)	Change in numbers
1-49 Acres	10,015	9,204	5,209	1,753	1,355	1,074	-8,941
50-179 acres	3,674	3,645	2,693	1,747	1,468	1,299	-2,357
180-999 acres	622	668	679	751	685	573	-49
1000 and larger	30	58	55	67	60	79	+49

Area V Southwest Rice Area

	(1940)	(1950)	(1959)	(1969)	(1974)	(1978)	change in numbers 1940-1978
1-49 acres	7,139	6,680	3,382	1,617	1,096	1,164	-5,975
50-179 acres	4,100	2,867	1,967	1,657	1,298	1,169	-2,931
180-999 acres	1,246	1,844	1,889	2,172	1,714	1,725	+479
1000 and larger	97	223	274	330	404	398	+301

Area VI South Central Mixed Farming Area

	(1940)	(1950)	(1959)	(1969)	(1974)	(1978)	change in numbers 1940-1978
1-49 acres	18,421	15,255	9,230	4,424	2,553	2,034	-16,387
50-179 acres	2,305	2,952	3,070	2,325	1,767	1,311	-994
180-999 acres	283	546	740	977	886	1,046	+763
1000 and larger	24	48	56	118	156	188	+164

(continued)

Table 3.—(Continued)

Area VII The Sugar Bowl Area

	(1940)	(1950)	(1959)	(1969)	(1974)	(1978)	change in numbers 1940–1978
1-49 acres	6,685	5,708	3,256	1,139	857	795	-5,890
50-179 acres	2,677	2,259	1,626	1,203	778	649	-2,028
180-999 acres	612	812	755	897	703	762	+150
1000 and larger	154	94	117	194	181	213	+59

Area VIII The Florida Parishes

	(1940)	(1950)	(1959)	(1969)	(1974)	(1978)	change in numbers 1940–1978
1-49 acres	9,769	9,542	5,460	1,921	1,419	1,319	-8,450
50-179 acres	3,131	3,285	2,663	1,754	1,534	1,370	-1,761
180-999 acres	568	725	715	768	756	854	+286
1000 and larger	46	45	40	40	40	39	-7

Area IX The New Orleans Truck and Fruit Area

	(1940)	(1950)	(1959)	(1969)	(1974)	(1978)	change in numbers 1940–1978
1-49 acres	2,035	2,052	979	370	362	429	-1,606
50-179 acres	545	576	347	276	197	242	-303
180-999 acres	104	172	117	120	89	88	-16
1000 and larger	25	37	16	23	30	28	+3

Compiled from the *Census of Agriculture* for the designated years.

(The New Orleans Truck and Fruit Area). From 1940 to 1978 there was a statewide increase of 1,832 farms of 180 to 999 acres. The change in numbers of farms of this size ranges from a high of 1,203 farms in Area III to a low (decrease) of 868 farms in Area II (North Louisiana Uplands). All but one area showed an increase in the number of farms of 1,000 acres or larger; the exception is Area VIII (The Florida Parishes) which showed a decrease of seven such farms. Those areas having the greatest increase in numbers of large (1,000 acres and larger) farms are Area III, where there was an increase of 394 such farms, and Area V (Southwest Rice Area) with an increase of 301 farms.

Hernandez and Acierto (1970: 7) point out that ''operators of larger farms are more likely to see the need for and to acquire certain equipment and other items of technology than are operators of smaller farms.'' The lower incidence of applying modern technology (machinery, etc.) may lead to a lower level of market competitiveness and purchasing power for needed tools and supplies. Smaller farm owners may therefore consider leaving the increasing farm-market competition to seek more lucrative sources of income. Small farms may be sold or rented, becoming in effect parts of larger farms.

The variables mechanization of farming, agricultural market competition, increased efficiency in planting and harvesting, and higher crop yields all point toward what Taylor and Roberts (1963: 12) refer to as the ''shift from traditionalistic to business oriented rural enterprise.'' This shift over the time period here considered has affected, in addition to the declining number of small farms and increasing number of large farms, the increasing value of the farms on a per acre basis.

Valuation of Louisiana Agricultural Land

Since 1940 there has been a consistent and considerable increase in rural land values in Louisiana's nine social areas. Although the figures in Table 4 are not adjusted for inflation over the years, and the changing definitions of "farm" have undoubtedly had an influence, some portion of the increase can be attributed to various changes which have developed in agricultural production processes. From approximately 1960 to the present the state's major field crops have been soybeans, rice, and cotton, with sugarcane production remaining at about the same level as in earlier times. Improvements in fertilizing and the use of chemicals, combined with land clearing for more farmable acreage, a shift in emphasis from beef cattle to soybeans (Woolf and Brugmann, 1973:6), as well as the introduction of various high quality and high yield grasses for grazing and hay (Rabb and Oakes, 1973: 13) are some of the agricultural changes leading to the higher crop yields and increases in the value of land.

> Land is a natural resource, fixed in location, with unique characteristics in terms of its basic composition, appearance, fertility, and topography. Moreover, the rural land market is usually limited to a small number of buyers and sellers. Normally there is a larger number of buyers than sellers (Ramsey and Corty, 1976:2).

In addition, highway networks encourage the development and growth of rural settlements which attract city dwellers resulting in increases in land prices. The Mississippi River also has an influence on nearby land values as port facilities are developed and industries locate along the waterway (Ramsey and Corty, 1976: 3-5). In all social areas of Louisiana the capital requirements of agriculture have rapidly increased due to increasing farm size, the displacement of labor by capital-intensive technology, increasing land values, and farmers having shifted from non-purchased inputs such as rainfall and family labor to purchased inputs such as equipment, fertilizer, and irrigation systems (Johnson, 1972:9).

All nine Louisiana social areas exhibit considerable increases in farm average value per acre (Table 4; see Appendix B, Table 3-B for Parish figures). Increases of 1978 average value per acre over the 1940 base figure range from a low of 1,378 percent (approximately 14 times the 1940 value) for Area IX (New Orleans truck and fruit area) to a high of 4,516 percent (approximately 45 times the 1940 value) for Area VIII (The Florida Parishes). Generally speaking, the average value of farms per acre in South Louisiana (social areas V through IX) consistantly has been somewhat greater than those of North Louisiana (areas I through IV).

Table 4.—Average value per acre of farms by social areas for selected years 1940-1978 in whole unadjusted dollars with percent over previous selected year

Area	1940	1950		1959		1969		1974	1978		Change In Dollars/Acre 1940-1978	Percent Increase Over 1940 Average Value Per Acre
	$	$	%	$	%	$	%	$	$	%		
I. Red River Delta	39	73	(87)	155	(112)	265	(71)	448(*)	858	(224)	+819	(2,100)
II. North Louisiana Uplands	22	55	(150)	127	(131)	224	(76)	422	769	(243)	+747	(3,395)
III. Mississippi Delta	36	62	(72)	127	(105)	279	(120)	449	914	(228)	+878	(2,438)
IV. North And West Central Cut-Over Area	21	55	(162)	132	(140)	214	(62)	420	784	(266)	+763	(3,633)
V. Southwest Rice Area	36	96	(167)	202	(110)	292	(45)	486	891	(205)	+855	(2,375)
VI. South Central Mixed Farming Area	55	130	(136)	246	(89)	403	(64)	649	1,298	(222)	+1,243	(2,260)
VII. Sugar Bowl Area	54	99	(83)	227	(129)	569	(151)	732	1,324	(133)	+1,270	(2,351)
VIII. Florida Parishes	30	100	(233)	249	(149)	445	(79)	773	1,385	(211)	+1,355	(4,516)
IX. New Orleans Truck and Fruit Area	82	137	(67)	479	(250)	506	(6)	701	1,212	(140)	+1,130	(1,378)

*Because 1974 is the exception to the approximately 10 year intervals the percent increase over 1969 is not included. The 1978 percent figure represents the increase over the 1969 average value per acre.

Compiled from the Census of Agriculture for the designated years.

Changing Land Tenure

In the state of Louisiana as a whole there has been a considerable decrease in the number of full owners and tenants from 1940 to 1978 (Table 5). Full owners increased in number from 1940 to 1950 (except in Area II, North Louisiana Uplands) followed by steady decreases to the present. Although real numbers of full owners decreased in all social areas 1940-1978 we find that in areas III, V, and VI there were gradual increases in relative percentage of state totals.

Most areas show relatively minor fluctuation over the years of numbers of part owners and percent of the state totals at selected times. However, rather substantial increases in part owners are noted in areas III, V, and VI and a marked decrease in Area VII. At the state wide level, the 1978 total number of part-owners represents approximately a 33 percent increase over the figure for 1940.

Throughout the state there has been a rather steady and sizable decrease in the number of tenants from 1940 to 1978. However certain social areas warrant further consideration. Social Area III (Mississippi Delta) had, in 1940, the largest proportion of tenant farmers—nearly 31 percent of the state total. In 1978 this area maintains the same rank position having 28 percent of the tenant farmers in the state. The Southwest Rice Area (V) increased in percentage of tenant farmers from 7.8 percent in 1940 to 21 percent of the state total in 1978. Likewise, the Sugar Bowl Area (VII) increased from having 5.6 percent of the state's tenant farmers in 1940 to 15.4 percent of the state total in 1978. (See Appendix, Tables 4-B, 5-B, and 6-B for parish figures related to full owners, part owners, and tenants respectively).

Recent Changing Trends

We have considered the general trends in changing Louisiana agriculture from 1940 to 1978 and found only minimal differences between social areas. Now we will briefly consider the 1974 to 1978 time frame for which the data are directly comparable, as the final reports for 1974 and the preliminary reports for 1978 utilize the same definition of farm which came into effect in August of 1975.

At the national level, in order that the 1978 data in the *Census of Agriculture* (Preliminary Report) be directly comparable to the 1974 data, the 1978 figures must be adjusted so as not to reflect the estimated national figures based on area segment samples which were not included in the 1974 *Census of Agriculture*. For example, to directly compare the 1974 and 1978 figures on the total number of farms in the United States, we must subtract the estimated 220,688 farms as discovered through the area segment sample. Following this procedure we find that nationwide the number of farms decreased from a 1974 total of 2,314,013 to 2,259,178 in 1978.

Table 5.—Numbers of full owners, part owners, and tenants with percent of state totals for selected years 1940-1978 by social areas

Area		1940		1950		1959		1969		1974		1978	
		Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
I. Red River Delta	Full owners	7,017	(13.3)	8,456	(13.5)	5,958	(13.5)	2,938	(11.9)	2,598	(12.9)	2,237	(12.8)
	Part owners	1,031	(14.0)	1,298	(11.1)	1,220	(10.7)	1,108	(10.1)	923	(10.5)	1,029	(10.5)
	Tenants	14,989	(16.8)	7,492	(15.2)	2,070	(11.3)	614	(9.1)	437	(10.0)	397	(9.1)
II. North Louisiana Uplands	Full owners	7,142	(13.5)	6,833	(10.9)	4,725	(10.7)	2,363	(9.6)	1,906	(9.5)	1,760	(10.1)
	Part owners	874	(11.9)	1,078	(9.2)	701	(6.1)	603	(5.5)	467	(5.3)	606	(6.2)
	Tenants	10,175	(11.4)	4,154	(8.4)	945	(5.2)	217	(3.2)	201	(4.6)	147	(3.4)
III. Mississippi Delta	Full owners	7,279	(14.0)	8,494	(13.5)	6,401	(14.5)	4,487	(18.2)	3,657	(18.2)	2,746	(15.8)
	Part owners	629	(8.5)	2,214	(18.9)	2,586	(22.7)	2,710	(24.8)	2,199	(25.1)	2,537	(25.8)
	Tenants	27,563	(30.9)	16,314	(33.2)	5,168	(28.3)	1,535	(22.7)	1,073	(24.7)	1,218	(28.0)
IV. North And West Central Cut-Over Area	Full owners	8,031	(15.2)	9,064	(15.1)	6,119	(13.8)	2,634	(10.7)	2,310	(11.5)	2,176	(12.5)
	Part owners	520	(7.1)	672	(5.7)	556	(4.9)	567	(5.2)	513	(5.8)	702	(7.1)
	Tenants	4,227	(4.7)	1,672	(3.4)	547	(3.0)	181	(2.7)	135	(3.1)	145	(3.3)
V. Southwest Rice Area	Full owners	4,630	(8.8)	5,822	(9.3)	3,769	(8.5)	2,496	(10.1)	2,003	(10.0)	1,919	(11.0)
	Part owners	1,290	(17.5)	1,964	(16.8)	2,027	(17.8)	2,026	(18.6)	1,639	(18.7)	1,721	(17.5)
	Tenants	6,961	(7.8)	4,023	(8.2)	1,992	(10.9)	1,251	(18.5)	873	(20.1)	916	(21.0)
VI. South Central Mixed Farming Area	Full owners	5,539	(10.5)	7,086	(11.3)	6,026	(13.6)	4,479	(18.2)	3,284	(16.3)	2,456	(14.1)
	Part owners	938	(12.7)	1,759	(15.0)	1,904	(16.7)	1,839	(16.8)	1,446	(16.5)	1,548	(15.7)
	Tenants	14,632	(16.4)	9,903	(20.1)	5,133	(28.1)	1,526	(22.6)	632	(14.5)	575	(13.2)
VII. Sugar Bowl Area	Full owners	3,410	(6.5)	4,414	(7.0)	2,876	(6.5)	1,208	(4.9)	989	(4.9)	922	(5.3)
	Part owners	1,385	(18.8)	1,565	(13.4)	1,389	(12.2)	1,162	(10.6)	800	(9.1)	796	(8.1)
	Tenants	5,011	(5.6)	2,881	(5.8)	1,499	(8.2)	1,053	(15.6)	719	(16.5)	671	(15.4)
VIII. Florida Parishes	Full owners	8,004	(15.2)	10,375	(16.5)	7,147	(16.2)	3,417	(13.9)	2,878	(14.3)	2,507	(14.4)
	Part owners	552	(7.5)	855	(7.3)	908	(8.0)	789	(7.2)	700	(8.0)	781	(7.9)
	Tenants	4,918	(5.5)	2,393	(4.9)	830	(4.5)	277	(4.1)	176	(4.0)	194	(4.4)
IX. New Orleans Truck And Fruit Area	Full owners	1,706	(3.2)	2,186	(3.5)	1,195	(2.7)	564	(2.3)	501	(2.5)	586	(3.4)
	Part owners	146	(2.0)	305	(2.6)	108	(0.9)	114	(1.0)	78	(0.9)	111	(1.1)
	Tenants	623	(0.7)	347	(0.7)	94	(0.5)	111	(1.6)	99	(2.3)	90	(2.1)
State Totals*	Full Owners	52,758	(100.2)	62,730	(100.6)	44,216	(100.0)	24,586	(99.8)	20,127	(100.1)	17,399	(99.4)
	Part owners	7,365	(100.0)	11,710	(100.0)	11,399	(100.0)	10,918	(99.8)	8,765	(99.9)	9,831	(99.9)
	Tenants	89,099	(99.8)	49,179	(99.9)	18,278	(100.0)	6,765	(100.1)	4,345	(99.8)	4,353	(99.9)

*Deviations from 100 percent due to rounding error.

Compiled from the Census of Agriculture for the designated years.

In considering the changing numbers of farms by size, we find that in the nation as a whole there was a decrease of 97,033 farms of 50 to 999 acres in size. Farms of 1,000 acres or more increased by 6,323 units. More interesting perhaps is the 1974 to 1978 national increase in number of farms of 1 to 49 acres which amounted to 35,875 units. The extent to which this increase in small farms is related to the reversal of the nationwide rural to urban migration trend which becomes noticeable in the early 1970's (Beale, 1975 and 1976) remains unclear and will be the focus of a bulletin presently in preparation.

In comparing the national trend related to the 1974 to 1978 change in number of farms of various sizes with Louisiana trends we find that although in the nation as a whole there was a 7.1 percent increase in the number of small farms (1 to 49 acres), there was in Louisiana a 7.4 percent decrease of farms in that size range (Table 6).

The number of medium-sized farms (50 to 999 acres) decreased for both the U.S. and Louisiana by nearly 6 percent. However, the increase in the number of large farms (1,000 or more acres) in Louisiana was nearly twice that of the national rate, 7.8 percent and 4.1 percent, respectively.

Finally, we will briefly consider 1974 to 1978 alterations in three major trends in the structure of agriculture in Louisiana—(1) the decrease in the number of farms, (2) the increase in the size of farms, and (3) the decrease in the number of tenant farmers. In examining Appendix B, Tables 1, 2, and 3 which present parish as well as social area data, we find numerous exceptions to the trends noted above which appear almost exclusively in the 1978 data columns, suggesting possible initial alterations in the general historical trends.

The first trend to be considered is the decrease in the number of farms in the state. Between 1974 and 1978 a total of 23 parishes showed an increase in the number of farms, and three parishes showed no change (Appendix B, Table 1-B). This resulted in three social areas (areas IV, V, and IX) exhibiting by 1978 an increase in number of farms during the previous 4 years.

Table 6.—Change in number and percent of farms of various sizes in the United States and Louisiana from 1974 to 1978

Farm size in acres	United States 1974	United States 1978	United States Percent change	Louisiana 1974	Louisiana 1978	Louisiana Percent change
1-49	507,797	543,672	+7.1	10,942	10,129	-7.4
50-999	1,651,279	1,554,246	-5.9	20,462	19,291	-5.7
1,000 and larger	154,937	161,260	+4.1	1,836	1,979	+7.8

From 1978 Census of Agriculture (preliminary report)

The second trend is the increase in size of farms in acres. In 1978, the average-sized farms in 20 of the 63 parishes actually decreased in size from the 1974 average farm acreage (Appendix B, Table 2-B). Sufficient proportions of these parishes were clustered that social areas IV, V, and IX showed an overall decrease in size of farms from 1974 to 1978.

The third trend here considered concerns the numbers of tenant farmers which have fairly consistently decreased in all parishes from 1940 to 1974 (Table 6-B). However, in 1978 we find that there was an increase in the number of tenants over the 1974 figure in 28 parishes which are sufficiently clustered to result in increases in tenant farmers in four social areas (III, IV, V, and VIII).

In summary then, we find that the following social areas are in various respects unique in manifesting at least temporary trend reversals between 1974 and 1978:

a) Area III (Mississippi Delta Area)—an increase in the number of tenant farmers.

b) Area IV (North Central and West Central Cut-Over Area)—the number of farms is increasing, and farms here are getting smaller on the average. Also, the number of tenant farmers is increasing.

c) Area V (The Southwest Rice Area)—the number of farms is increasing and farms here are getting smaller on the average. Also, the number of tenant farmers is increasing.

d) Area VIII (The Florida Parishes)—there is an increase in the number of tenant farmers.

e) Area IX (The New Orleans Truck and Fruit Area)—the number of farms is increasing and the average farm was smaller in 1978 than 1974.

At the national level, since the early 1970's, there has appeared the trend of increasing numbers of large farms in high quality farming areas as commercial farms increase in number through absorbing smaller farms and bringing new areas into production. In Louisiana this trend is exemplified by Area III (Mississippi Delta Area) and Area VII (Sugar Bowl Area) where there was an increase in the number of farms of 180 acres and larger and a decrease in the number of farms of 1 to 179 acres between 1974 and 1978 (Table 3). However, this trend does not appear to hold true for other large-scale commercial farming areas in the state such as Area I (Red River Delta) and Area V (Southwest Rice Area).

Along with the above mentioned national trend there is also evidenced the trend toward increasing numbers of small farms in those areas considered non-commercial or less than prime farming areas. This trend is approximated in Louisiana in Area II (North Louisiana Uplands) where there is evidence of a moderate increase in the number of small (1 to 49 acres) farms and Area IX (New Orleans Truck and Fruit Area) where we find a large increase in the number of small farms (1 to 179 acres) and virtually no increase in the number of larger farms (Table 3). However, other areas which might be considered less commercial (relatively small average farm size) such as Area IV (North and West Central Cut-Over Area), Area VI (South Central Mixed Farming Area), and Area VIII (Florida Parishes) do not appear to follow the national trend as small farms are decreasing and large farms are increasing in number.

It appears then that some of the recent national trends are not at present clearly evident in Louisiana. We anticipate that further research and analysis of *Census of Agriculture* data along with analysis of changing demographic characteristics will contribute to our understanding of the changing structure of agriculture in Louisiana.

Conclusions

American agriculture has undergone considerable change since 1940. Along with the continued migration of large numbers of people from rural agricultural to urban industrial areas the need for agricultural workers diminished sharply with the development and dispersal of agricultural technology. As T. Lynn Smith (1974:48) points out: "At various times and in many places the resort to the use of mechanical equipment in farming processes undoubtedly came as a response to the lack of human hands to do the work on the farm." He goes on to note, however, that "the remarkable development of motors and machines" for agricultural production "coupled with national agricultural policies of allotments and systems of benefit payments that grossly favored and heavily subsidized the large producers . . . has served to force the small general and subsistence farmer from the land."

Investment in expensive technology increased production while those unable to make such investments or unwilling to make the transition from traditionalistic to business-oriented rural enterprise, have tended to leave farming. Simultaneously . . .

> There has been a shift in entrepreneurial control and economic power away from the farm. There has arisen an organizational complex of farming operations and corporations supplying inputs or marketing products, no longer mediated by a competitive market. The degree of this development varies by type of products. (Gross, *et al.*, 1980:95).

It may be that some form of the small family farm will "survive" but it must adapt and adjust to an increasingly centralized economic system and a cost-price squeeze led by increasingly scarce energy (gas, oil, and fertilizers especially) if it is to provide the commodities needed by our heavily urbanized, growing population. If an alteration of the trend toward "superfarms" is viewed as desirable by society it appears that some measures must ". . . be used to restrain growth to superfarm sizes" (Heady, 1981:25). Such desirability remains a question for further consideration and research.

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Appendix A

Farm:

Because of changing definitions employed by United States *Census of Agriculture,* direct comparisons of the figures over time are not possible. However, general trends can be discerned. We will here consider the changing definition of ''farm'' to indicate the nature of the problem.

For the 1940 census of agriculture a farm was defined in part as a place of 3 or more acres producing agricultural products worth $150 or more, or a place of less than 3 acres producing agricultural products worth at least $250. The 1950 census defined a farm as a place of 3 or more acres producing $150 or more in products annually. Those places of less than 3 acres were also considered farms if the annual production value was $150 or more excluding home gardens. In the 1959, 1969, and 1974 (preliminary report) census years, a ''farm'' was defined as 10 or more acres with a $50 or more annual value of agricultural products as well as units of less than 10 acres when $250 or more worth of products was sold. The 1974 (final reports) and 1978 definition of ''farm'' is any place from which $1,000 or more of agricultural products were sold or normally would have been sold during the census year. As Reiling and Wiegmann (1979:20) point out,

> Each change in the definition of a farm reduced the number of units that were classified as a farm, thus causing part of the decrease in the number of farms. Some of the units should probably never have been classified as farms in the first place. Their inclusion overstated a base for measurement which now leads to an overstatement of the extent of decline in farm numbers.

Additionally, the *Census of Agriculture* reports an inflated number of farms because a plantation with X number of sharecroppers is counted as X separate farms. As a result, some of the decline in number of farms,

> . . . in Louisiana and in the South, is more fictitious than real. The same farm unit is still there, operated now by hired labor rather than share croppers and, as a result, it's now counted as one farm rather than a dozen or twenty (Wiegmann, 1961:4)

An additional problem affecting the comparability of 1978 parish (county) data to state, regional, and United States data centers on the problem of data collection. According to the 1978 *Census of Agriculture* preliminary report, ''the 1978 census data collection program was the first to include an area segment sample to provide reliable estimates, for states, regions, and the United States, of the number and characteristics of any farms not represented in the mail portion of the census.'' These estimates are not included in county totals. These estimates have resulted in the discovery of an estimated additional 7,584 ''farms'' in Louisiana as currently defined. The summation of parish numbers of farms as reported in the 1978 *Census of Agriculture—Preliminary Report* (for parishes) equals 31,389, while the adjusted figure for the state of Louisiana is 38,973 or an increase of about 24 percent in number of farms.

Farms by Size:

Farms were classified by size according to the total land area established for each farm. The same classification was used for all states. According to definition, a farm is essentially an operating unit, not an ownership tract. All land operated by one person or partnership represents one farm. In the case of a landlord who has assigned land to croppers or other tenants, the land assigned to each cropper or tenant is considered a separate farm even though the landlord may operate the entire landholding as one unit in respect to supervision, equipment, rotation practice, purchase of supplies, or sale of products. In some parts of the south, a special Landlord-Tenant Questionnaire was used to assure an accurate enumeration of each unit within a multiple-unit operation. A change was made in the size classification for 1959, as contrasted with several preceding years, by subdividing the 1,000-acre-and-over group and by combining two previously recognized groups, i.e., 10 to 29 acres and 30 to 49 acres.

Value of Land and Buildings:

The enumerator was instructed to record the market value of the land and the buildings on that land. Market value was defined as the price which the farm operator would expect to receive for the land and buildings if he were to sell them on the day of enumeration. This classification also applies to value/farms and value/acre. The dollar values reported are not directly comparable from year to year as indicating actual changes in the production potential of farms since the dollar figures are not adjusted for inflation. Also, because of changing definitions of ''farm,'' which in part reflects concern with the inflation factor, we assume that small and/or marginally productive units are being deleted which too would tend to raise the average value per acre of farms. We cannot assume equal distribution throughout the state of farms so deleted.

Farm Operators:

This is a person who operates a farm, either performing the labor himself or directly supervising it. The Census definition of a farm is on the basis of operating units, rather than ownership tracts. A farm may be held under different tenures, or one tract may be owned and another tract rented by the farm operator. Similarly, when a landowner has several tenants, renters, or croppers, the land operated by each is considered a separate farm. Therefore, the number of farm operators, for all practical purposes is identical with the number of farms and these items are used interchangeably.

Farms by Tenure of Operator:

a. Full Owners operate only land they own.

b. Part Owners operate land they own and also land rented from others.

c. Tenants rent from others or work on shares for others all the land they operate. They are further classified on the basis of rental arrangements in regard to the payment of cash rent, sharing of crops, of livestock or livestock products, and the furnishing of work power by the landlord.

Appendix B

The Tables herein are expanded versions of those found in the text in that data is presented at the parish as well as Social Area level.

Table 1-B	Number and percent of farms
2-B	Average Size of Farms
3-B	Average Value per Acre
4-B	Number of Full Owners
5-B	Number of Part Owners
6-B	Number of Tenants

Table 1-B.—Number and percent of farms in Louisiana parishes and social areas for selected years 1940-1978

AREA I (Red River Delta)	1940	1950	1959	1969	1974	1978
Bossier	3,079	2,018	1,286	537	432	419
Caddo	5,061	3,400	1,532	807	656	612
DeSoto	4,397	2,689	1,670	877	688	662
Natchitoches	4,886	3,564	1,761	881	802	686
Rapides	3,368	3,855	2,338	1,130	1,053	986
Red River	2,338	1,804	720	428	327	294
Area Total	23,129	17,330	9,307	4,660	3,958	3,659
Percent	(15.4)	(14.0)	(12.5)	(11.6)	(11.9)	(11.6)
AREA II (North La. Uplands)						
Bienville	3,083	2,126	976	548	386	349
Claiborne	3,758	2,568	1,198	535	414	390
Lincoln	2,842	1,949	835	482	383	330
Ouchita	2,499	1,615	972	499	384	460
Union	3,248	1,899	1,230	574	493	498
Webster	2,785	1,930	1,210	545	511	486
Area Total	18,215	12,087	6,421	3,183	2,571	2,513
Percent	(12.1)	(9.7)	(8.6)	(7.5)	(7.7)	(8.0)
AREA III (Mississippi Delta)	1940	1950	1959	1969	1974	1978
Catahoula	2,219	1,668	995	671	530	574
Concordia	1,824	1,308	710	443	365	419
East Carroll	2,876	2,038	759	445	387	374
East Feliciana	1,971	1,669	900	503	502	449
Franklin	5,865	4,739	2,654	1,701	1,272	1,077
Madison	2,524	1,669	735	443	358	409
Morehouse	3,744	3,166	1,462	726	511	450
Point Coupee	2,828	2,235	1,299	811	600	566
Richland	4,866	3,585	1,887	1,146	877	734
Tensas	2,371	1,705	750	459	338	334
West Carroll	3,275	2,570	1,615	1,163	971	831
West Feliciana	1,253	801	495	221	218	184
Area Total	35,616	27,153	14,261	87,332	6,929	6,401
Percent	(23.7)	(21.9)	(19.2)	(20.6)	(20.8)	(20.4)
AREA IV (North and West Central Cut-Over Area)						
Beauregard	1,709	1,702	1,045	828	695	798
Caldwell	1,252	1,111	660	333	276	284
Grant	1,423	1,481	857	347	302	282
Jackson	1,638	993	519	232	269	229
LaSalle	704	851	666	283	196	212
Sabine	2,540	1,918	1,337	566	460	472
Vernon	1,885	1,991	1,398	575	523	535
Winn	1,641	1,373	750	218	237	211
Area Total	12,792	11,420	7,232	3,382	2,958	3,023
Percent	(8.5)	(9.2)	(9.7)	(8.0)	(8.9)	(9.6)

(continued)

Table 1-B.—(Continued)

AREA V (Southwest Rice Area)	1940	1950	1959	1969	1974	1978
Acadia	3,937	3,346	2,471	1,453	1,025	1,026
Allen	1,302	1,295	767	523	369	394
Calcasieu	1,776	1,896	771	739	665	692
Cameron	842	592	479	423	329	397
Jefferson Davis	1,665	1,553	1,049	897	652	652
Vermilion	3,392	3,180	2,299	1,738	1,475	1,395
Area Total	12,914	11,862	7,836	5,773	4,515	4,556
Percent	(8.6)	(9.6)	(10.5)	(13.6)	(13.6)	(14.5)
AREA VI (South Central La. Mixed Farming)						
Avoyelles	5,242	4,563	3,098	2,009	1,521	1,419
Evangeline	4,578	3,892	2,706	1,519	932	777
Lafayette	3,441	2,977	2,272	1,452	1,009	813
St. Landry	7,883	7,369	5,029	2,864	1,900	1,570
Area Total	21,144	18,801	13,105	7,844	5,362	4,579
Percent	(14.1)	(15.1)	(17.6)	(18.6)	(16.1)	(14.6)
AREA VII (The Sugar Bowl Area)						
Ascension	1,411	1,455	896	293	243	255
Assumption	551	409	307	194	143	145
Iberia	1,314	1,069	805	591	401	401
Iberville	741	681	425	286	241	234
Lafourche	1,120	1,058	758	519	356	399
St. James	434	406	208	145	117	116
St. John	181	195	83	47	48	42
St. Martin	2,440	2,238	1,432	774	566	434
St. Mary	387	391	271	216	148	113
Terrebonne	917	726	428	217	129	131
West Baton Rouge	501	404	269	141	116	119
Area Total	9,997	9,032	5,882	3,423	2,508	2,389
Percent	(6.7)	(7.3)	(7.9)	(8.1)	(7.5)	(7.6)
AREA VIII (The Florida Parishes)	1940	1950	1959	1969	1974	1978
East Baton Rouge	1,853	1,981	1,103	675	557	538
Livingston	2,162	2,397	1,520	489	479	459
St. Helena	1,709	1,533	1,045	594	489	413
Tangipahoa	4,521	4,551	2,985	1,513	1,190	1,155
Washington	3,261	3,190	2,266	1,212	1,039	917
Area Total	13,506	13,652	8,919	4,483	3,754	3,482
Percent	(9.0)	(11.0)	(12.0)	(10.6)	(11.3)	(11.1)
AREA IX (New Orleans Truck and Fruit Area)						
Jefferson	284	254	119	54	37	70
Orleans	199	110	69	0	0	0
Plaquemines	602	596	419	111	102	126
St. Bernard	111	170	53	27	21	29
St. Charles	253	259	110	71	60	55
St. Tammany	1,245	1,455	705	526	458	507
Area Total	2,694	2,844	1,475	789	678	787
Percent	(1.8)	(2.3)	(2.0)	(1.9)	(2.0)	(2.5)
State Wide Total	150,007	124,181	74,438	42,269	33,233	31,389
Percent*	(99.9)	(100.1)	(100.0)	(99.9)	(99.8)	(99.9)

*Deviations from 100 percent due to rounding error.
Compiled from *Census of Agriculture* for the designated years

Table 2-B.—Average size of farms in areas by parish and social areas for selected years 1940-1978

AREA I (Red River Delta)	1940	1950	1959	1969	1974	1978
Bossier	71	94	181	338	302	303
Caddo	58	84	176	344	383	385
DeSoto	70	123	178	281	273	290
Natchitoches	57	81	153	304	314	370
Rapides	67	70	112	175	203	196
Red River	71	96	209	307	367	447
Social Area Average	X̄=66	X̄=91	X̄=168	X̄=292	X̄=307	X̄=332
AREA II (North La. Uplands)						
Bienville	82	99	127	174	158	188
Claiborne	94	123	158	212	218	249
Lincoln	88	97	142	160	170	186
Ouachita	69	88	126	224	236	238
Union	77	105	114	156	154	161
Webster	82	99	121	190	162	173
Social Area Average	X̄=82	X̄=102	X̄=131	X̄=186	X̄=183	X̄=199
AREA III (Mississippi Delta)						
Catahoula	48	80	125	304	390	444
Concordia	93	130	294	537	601	633
East Carroll	44	93	236	474	591	629
East Feliciana	98	147	222	367	309	319
Franklin	41	64	116	192	240	290
Madison	67	142	282	548	665	652
Morehouse	56	64	144	370	549	632
Point Coupee	70	105	180	282	328	360
Richland	43	71	134	230	313	369
Tensas	88	157	327	512	677	709
West Carroll	46	68	114	169	190	220
West Feliciana	101	198	279	550	574	554
Social Area Average	X̄=66	X̄=110	X̄=204	X̄=378	X̄=452	X̄=484
AREA IV (North and West Central Cut-Over Area)	1940	1950	1959	1969	1974	1978
Beauregard	67	101	153	190	230	205
Caldwell	61	70	104	184	219	248
Grant	58	68	93	181	184	188
Jackson	79	78	91	125	143	120
LaSalle	49	50	52	77	89	102
Sabine	67	78	99	146	140	132
Vernon	56	52	70	110	175	142
Winn	64	61	78	117	123	153
Social Area Average	X̄=63	X̄=70	X̄=92	X̄=141	X̄=163	X̄=161
AREA V (Southwest Rice Area)						
Acadia	76	95	137	231	327	328
Allen	79	91	196	308	404	344
Calcasieu	102	212	608	546	614	589
Cameron	85	282	452	679	746	658
Jefferson Davis	162	226	339	408	503	527
Vermilion	93	127	168	226	254	272
Social Area Average	X̄=100	X̄=172	X̄=317	X̄=400	X̄=475	X̄=453
AREA VI (South Central La. Mixed Farming)						
Avoyelles	33	51	74	128	172	217
Evangeline	40	54	80	146	222	283
Lafayette	40	44	62	94	111	132
St. Landry	36	44	62	117	163	207
Social Area Average	X̄=37	X̄=48	X̄=70	X̄=98	X̄=167	X̄=210

(continued)

Table 2-B.—(Continued)

AREA VII (The Sugar Bowl Area)	1940	1950	1959	1969	1974	1978
Ascension	44	108	479	695	894	1,497
Assumption	50	86	163	434	546	1,118
Iberia	58	117	226	420	690	1,455
Iberville	44	99	193	483	589	1,185
Lafourche	30	77	164	441	531	791
St. James	46	85	229	821	1,071	1,897
St. John	77	89	209	1,287	1,284	1,932
St. Martin	46	100	193	386	563	912
St. Mary	35	89	176	396	493	1,140
Terrebonne	45	117	186	426	550	1,081
West Baton Rouge	125	125	283	466	838	1,551
Social Area Average	$\bar{X}$=54	$\bar{X}$=99	$\bar{X}$=227	$\bar{X}$=569	$\bar{X}$=732	$\bar{X}$=1,324
AREA VIII (The Florida Parishes)						
East Baton Rouge	41	131	394	739	975	1,821
Livingston	35	128	307	461	1,003	1,726
St. Helena	17	65	128	290	528	855
Tangipahoa	33	110	238	424	716	1,289
Washington	24	66	176	313	645	1,234
Social Area Average	$\bar{X}$=30	$\bar{X}$=100	$\bar{X}$=249	$\bar{X}$=445	$\bar{X}$=773	$\bar{X}$=1,385
AREA IX (New Orleans Truck and Fruit Area)						
Jefferson	171	160	558	1,023	994	1,592
Plaquemines	55	145	307	300	537	897
St. Bernard	111	182	947	289	577	642
St. Charles	41	93	373	384	404	968
St. Tammany	33	105	210	532	995	1,959
Social Area Average	$\bar{X}$=82	$\bar{X}$=137	$\bar{X}$=479	$\bar{X}$=506	$\bar{X}$=701	$\bar{X}$=1,212

Compiled from *Census of Agriculture* for designated years

Table 3-B. —Average value of farms per acre by parish and social areas for selected years 1940-1978 in whole unadjusted dollars

AREA I (Red River Delta)	1940	1950	1959	1969	1974	1978
Bossier	45	75	193	276	521	912
Caddo	60	102	187	277	418	841
DeSoto	19	44	98	174	338	634
Natchitoches	30	64	111	234	455	843
Rapides	49	108	214	419	594	1,141
Red River	30	47	126	211	362	777
Social Area Average	$\bar{X}=39$	$\bar{X}=73$	$\bar{X}=155$	$\bar{X}=265$	$\bar{X}=448$	$\bar{X}=858$
AREA II (North La. Uplands)						
Bienville	16	34	95	168	333	627
Claiborne	18	44	87	171	306	564
Lincoln	21	57	119	251	427	774
Ouachita	37	100	230	385	684	1,200
Union	17	42	97	183	427	717
Webster	23	53	134	183	352	732
Social Area Average	$\bar{X}=22$	$\bar{X}=55$	$\bar{X}=127$	$\bar{X}=224$	$\bar{X}=422$	$\bar{X}=769$
AREA III (Mississippi Delta)						
Catahoula	30	59	115	245	415	824
Concordia	26	61	119	242	404	761
East Carroll	55	64	156	363	516	1,079
East Feliciana	17	43	132	241	461	895
Franklin	38	72	127	299	478	881
Madison	42	59	148	318	497	1,045
Morehouse	35	69	127	298	475	1,029
Point Coupee	40	87	124	253	454	950
Richland	41	72	130	275	414	942
Tensas	34	50	121	256	439	915
West Carroll	41	76	124	295	428	960
West Feliciana	27	31	99	259	410	686
Social Area Average	$\bar{X}=36$	$\bar{X}=62$	$\bar{X}=127$	$\bar{X}=279$	$\bar{X}=449$	$\bar{X}=914$
AREA IV (North and West Central Cut-Over Area)	1940	1950	1959	1969	1974	1978
Beauregard	21	45	119	229	437	769
Caldwell	26	69	128	292	394	788
Grant	30	66	189	240	576	803
Jackson	17	50	112	217	368	819
LaSalle	23	69	164	331	443	901
Sabine	17	48	100	201	369	750
Vernon	18	45	125	214	437	714
Winn	18	50	117	201	340	724
Social Area Average	$\bar{X}=21$	$\bar{X}=55$	$\bar{X}=132$	$\bar{X}=241$	$\bar{X}=420$	$\bar{X}=784$
AREA V (Southwest Rice Area)						
Acadia	54	138	244	368	560	1,083
Allen	21	74	190	230	433	781
Calcasieu	36	95	185	286	505	743
Cameron	21	49	149	162	366	662
Jefferson Davis	40	106	212	325	502	958
Vermilion	46	113	229	384	553	1,120
Social Area Average	$\bar{X}=36$	$\bar{X}=96$	$\bar{X}=202$	$\bar{X}=292$	$\bar{X}=486$	$\bar{X}=891$
AREA VI (South Central La. Mixed Farming)						
Avoyelles	57	92	161	307	575	1,009
Evangeline	39	104	196	316	532	958
Lafayette	71	188	386	650	973	2,198
St. Landry	52	136	240	339	516	1,085
Social Area Average	X=55	X=130	X=246	X=403	X=649	X=1,298

(continued)

Table 3-B.—(Continued)

AREA VII (The Sugar Bowl Area)	1940	1950	1959	1969	1974	1978
Ascension	53	78	100	219	232	231
Assumption	171	249	309	437	536	533
Iberia	84	126	172	222	275	318
Iberville	126	164	283	428	459	447
Lafourche	228	238	312	394	573	520
St. James	133	171	254	392	402	437
St. John	176	245	394	480	560	500
St. Martin	53	55	68	128	162	203
St. Mary	293	411	516	561	794	807
Terrebonne	125	160	235	461	468	494
West Baton Rouge	91	126	201	392	323	311
Social Area Average	$\bar{X}=139$	$\bar{X}=184$	$\bar{X}=258$	$\bar{X}=374$	$\bar{X}=435$	$\bar{X}=436$
AREA VIII (The Florida Parishes)						
East Baton Rouge	82	88	137	198	222	199
Livingston	38	39	44	92	90	97
St. Helena	66	63	86	120	139	152
Tangipahoa	43	46	62	105	126	133
Washington	66	72	86	113	121	135
Social Area Average	$\bar{X}=59$	$\bar{X}=62$	$\bar{X}=83$	$\bar{X}=126$	$\bar{X}=140$	$\bar{X}=143$
AREA IX (New Orleans Truck and Fruit Area)						
Jefferson	41	124	141	166	206	257
Plaquemines	76	101	94	286	374	375
St. Bernard	52	62	242	263	357	232
St. Charles	114	233	399	474	951	505
St. Tammany	63	87	112	152	142	139
Social Area Average	$\bar{X}=69$	$\bar{X}=121$	$\bar{X}-198$	$\bar{X}=268$	$\bar{X}=406$	$\bar{X}=302$

Compiled from *Census of Agriculture* for the designated Years

Table 4-B.—Numbers of full owners with area percent of state totals for selected years by parish and social areas

Area I (Red River Delta)	1940	1950	1959	1969	1974	1978
Bossier	1,024	1,018	899	330	281	258
Caddo	1,071	1,092	701	433	353	308
DeSoto	1,361	1,371	1,101	608	477	449
Natchitoches	1,485	1,578	1,162	590	583	429
Rapides	1,582	2,756	1,662	704	704	621
Red River	494	641	433	273	200	172
Area Total	7,017	8,456	5,958	2,938	2,598	2,237
Percent	(13.3)	(13.5)	(13.5)	(11.9)	(12.9)	(12.8)
Area II (North La. Uplands)						
Bienville	1,328	1,403	740	415	280	263
Claiborne	1,083	1,101	733	376	293	269
Lincoln	1,102	1,158	690	383	284	231
Ouachita	935	908	685	336	279	300
Union	1,670	1,114	986	466	398	375
Webster	1,024	1,149	891	387	369	322
Area Total	7,142	6,833	4,725	2,363	1,906	1,760
Percent	(13.5)	(10.9)	(10.7)	(9.6)	(9.5)	(10.1)

Area III (Mississippi Delta)	1940	1950	1959	1969	1974	1978
Catahoula	607	674	633	389	296	255
Concordia	327	416	364	204	166	147
East Carroll	471	563	339	191	154	121
East Feliciana	568	774	614	343	366	302
Franklin	1,180	1,353	1,035	891	658	449
Madison	239	377	329	209	178	163
Morehouse	588	936	634	375	280	159
Point Coupee	516	637	487	353	296	238
Richland	1,040	981	736	609	478	312
Tensas	327	343	278	205	173	115
West Carroll	1,216	1,223	812	628	499	396
West Feliciana	200	217	140	90	113	89
Area Total	7,279	8,494	6,401	4,487	3,657	2,746
Percent	(14.0)	(13.5)	(14.5)	(18.2)	(18.2)	(15.8)

Area IV (North and West Central Cut-Over Area)	1940	1950	1959	1969	1974	1978
Beauregard	1,288	1,327	836	606	505	548
Caldwell	731	772	523	213	168	169
Grant	746	1,035	708	249	234	201
Jackson	812	769	474	198	229	173
LaSalle	498	700	545	227	153	150
Sabine	1,488	1,579	1,115	493	383	351
Vernon	1,365	1,745	1,225	473	432	422
Winn	1,103	1,137	693	175	206	162
Area Total	8,031	9,064	6,119	2,634	2,310	2,176
Percent	(15.2)	(15.1)	(13.8)	(10.7)	(11.5)	(12.5)
Area V (Southwest Rice Area)						
Acadia	1,052	1,145	1,013	646	445	408
Allen	795	951	534	301	190	202
Calcasieu	852	1,352	405	301	301	312
Cameron	319	333	334	227	147	186
Jefferson Davis	448	707	456	290	229	199
Vermilion	1,164	1,334	1,027	731	691	612
Area Total	4,630	5,822	3,769	2,496	2,003	1,919
Percent	(8.8)	(9.3)	(8.5)	(10.1)	(10.0)	(11.0)

Table 4-B.—(Continued)

Area VI (South Central La. Mixed Farming)	1940	1950	1959	1969	1974	1978
Avoyelles	1,598	2,138	1,747	1,176	879	663
Evangeline	1,213	1,531	1,238	830	580	399
Lafayette	960	1,058	992	830	588	507
St. Landry	1,768	2,359	2,049	1,643	1,237	887
Area Total	5,539	7,086	6,029	4,479	3,284	2,456
Percent	(10.5)	(11.3)	(13.6)	(18.2)	(16.3)	(14.1)
Area VII (The Sugar Bowl Area						
Ascension	812	1,140	680	170	141	146
Assumption	248	213	130	41	45	42
Iberia	387	429	383	225	169	179
Iberville	219	323	167	78	65	56
Lafourche	403	516	348	172	119	133
St. James	143	231	77	22	24	21
St. John	67	117	37	9	16	13
St. Martin	519	634	605	297	266	195
St. Mary	133	125	80	55	53	27
Terrebonne	464	498	265	87	43	62
West Baton Rouge	75	188	104	52	48	48
Area Total	3,470	4,414	2,876	1,208	989	922
Percent	(6.5)	(7.0)	(6.5)	(4.9)	(4.9)	(5.3)
Area VIII (The Florida Parishes)	1940	1950	1959	1969	1974	1978
East Baton Rouge	1,021	1,493	861	407	367	335
Livingston	1,473	2,087	1,393	421	385	370
St. Helena	881	958	751	450	372	294
Tangipahoa	2,697	3,585	2,414	1,172	927	856
Washington	1,932	2,252	1,728	967	827	652
Area Total	8,004	10,375	7,147	3,417	2,878	2,507
Percent	(15.2)	(16.5)	(16.2)	(13.9)	(14.3)	(14.4)
Area IX (New Orleans Truck and Fruit Area)						
Jefferson	134	179	81	26	16	43
Plaquemine	462	451	364	66	72	89
St. Bernard	39	113	46	17	15	20
St. Charles	84	164	54	22	11	18
St. Tammany	987	1,279	650	433	387	416
Area Total	1,706	2,186	1,195	564	501	586
Percent	(3.2)	(3.5)	(2.7)	(2.3)	(2.5)	(3.4)
Statewide Total	52,758	62,730	44,216	24,586	20,127	17,399
Percent*	(100.2)	(100.6)	(100.0)	(99.8)	(100.1)	(99.4)

*Deviations from 100 percent due to rounding error.
Compiled from *Census of Agriculture* for designated years.

Table 5-B.—Number of part owners with area percent of state totals for selected years by parish and social areas

AREA I (Red River Delta)	1940	1950	1959	1969	1974	1978
Bossier	117	206	174	134	107	114
Caddo	275	185	216	225	189	199
DeSoto	186	266	256	178	146	161
Natchitoches	194	239	176	199	146	192
Rapides	162	238	295	265	240	267
Red River	97	164	103	107	95	96
Area Total	1,031	1,298	1,220	1,108	923	1,029
Percent	(14.0)	(11.1)	(10.7)	(10.1)	(10.5)	(10.5)
AREA II (North La. Uplands)						
Bienville	148	215	123	104	66	74
Claiborne	193	220	156	112	84	100
Lincoln	177	163	61	80	67	83
Ouachita	82	102	97	102	66	115
Union	137	215	120	79	77	104
Webster	137	163	144	126	107	130
Area Total	874	1,078	701	603	467	606
Percent	(11.9)	(9.2)	(6.1)	(5.5)	(5.3)	(6.2)
AREA III (Mississippi Delta)	1940	1950	1959	1969	1974	1978
Catahoula	28	129	123	191	171	223
Concordia	34	47	93	166	132	187
East Carroll	33	163	182	173	147	158
East Feliciana	43	112	91	104	93	119
Franklin	75	437	478	546	419	476
Madison	33	128	155	155	121	170
Morehouse	80	214	240	232	152	184
Point Coupee	86	260	254	203	175	193
Richland	78	279	390	368	265	315
Tensas	29	128	118	128	102	129
West Carroll	71	268	404	383	356	315
West Feliciana	39	49	58	61	66	68
Area Total	629	2,214	2,586	2,710	2,199	2,537
Percent	(8.5)	(18.9)	(22.7)	(24.8)	(25.1)	(25.8)
AREA IV (North and West Central Cut-Over Area)						
Beauregard	48	130	131	165	153	201
Caldwell	34	80	76	86	87	92
Grant	41	102	63	70	51	69
Jackson	94	56	21	27	31	45
LaSalle	42	55	51	35	33	54
Sabine	69	99	94	64	59	100
Vernon	115	86	98	87	78	102
Winn	77	64	22	33	21	39
Area Total	520	672	556	567	513	702
Percent	(7.1)	(5.7)	(4.9)	(5.2)	(5.8)	(7.1)

(continued)

Table 5-B.—(Continued)

AREA V (Southwest Rice Area)	1940	1950	1959	1969	1974	1978
Acadia	345	468	520	490	389	383
Allen	110	131	139	157	132	136
Calcasieu	131	212	226	252	225	253
Cameron	41	108	91	138	135	158
Jefferson Davis	227	349	322	320	245	276
Vermilion	436	696	729	669	513	515
Area Total	1,290	1,964	2,027	2,026	1,639	1,721
Percent	(17.5)	(16.8)	(17.8)	(18.6)	(18.7)	(17.5)
AREA VI (South Central La. Mixed Farming)						
Voyelles	478	805	727	631	518	590
Evangeline	115	274	308	329	246	283
Lafayette	200	260	379	337	262	210
St. Landry	145	420	490	542	420	465
Area Total	939	1,759	1,904	1,839	1,446	1,548
Percent	(12.7)	(15.0)	(16.7)	(16.8)	(16.5)	(15.7)
Area VII (The Sugar Bowl Area)						
Ascension	141	169	142	81	68	73
Assumption	83	93	84	59	38	48
Iberia	208	240	220	221	141	135
Iberville	91	114	116	91	93	84
Lafourche	222	226	207	185	120	121
St. James	115	84	82	57	36	56
St. John	32	37	27	19	10	12
St. Martin	210	329	285	240	177	146
St. Mary	71	105	79	83	39	43
Terrebonne	137	112	85	70	42	35
West Baton Rouge	75	56	62	56	36	43
Area Total	1,385	1,565	1,389	1,162	800	796
Percent	(18.8)	(13.4)	(12.2)	(10.6)	(9.1)	(8.1)
Area VIII (The Florida Parishes)	1940	1950	1959	1969	1974	1978
East Baton Rouge	120	166	157	181	136	149
Livingston	64	88	56	54	81	78
St. Helena	98	159	139	113	97	93
Tangipahoa	100	171	253	249	200	232
Washington	170	271	303	192	186	229
Area Total	552	855	908	789	700	781
Percent	(7.5)	(7.3)	(8.0)	(7.2)	(8.0)	(7.9)
Area IX (New Orleans Truck and Fruit Area)						
Jefferson	33	21	20	11	8	9
Plaquemines	26	57	21	17	16	24
St. Bernard	19	32	2	3	3	4
St. Charles	40	159	34	15	7	12
St. Tammany	28	36	31	68	44	62
Area Total	146	305	108	114	78	111
Percent	(2.0)	(2.6)	(0.9)	(1.0)	(0.9)	(1.1)
Statewide Total	7,365	11,710	11,399	10,918	8,765	9,831
Percent*	(100.0)	(100.0)	(100.0)	(99.8)	(99.9)	(99.9)

*Deviations from 100 percent due to rounding error.
Compiled from Census of Agriculture for designated years.

Table 6-B.—Number of tenants with area percent of state totals for selected years by parish and social areas

AREA I (Red River Delta)	1940	1950	1959	1969	1974	1978
Bossier	1,919	790	205	73	44	51
Caddo	3,694	2,097	597	149	114	105
DeSoto	2,847	1,044	303	91	65	52
Natchitoches	3,190	1,725	415	92	73	65
Rapides	1,602	844	369	161	109	98
Red River	1,737	992	181	48	32	26
Area Total	14,989	7,492	2,070	614	437	397
Percent	(16.8)	(15.2)	(11.3)	(9.1)	(10.0)	(9.1)
AREA II (North La. Uplands						
Bienville	1,604	505	112	29	40	12
Claiborne	2,481	1,242	301	47	37	21
Lincoln	1,559	623	78	19	32	16
Ouachita	1,474	598	179	61	39	45
Union	1,439	570	115	29	18	19
Webster	1,618	616	160	32	35	34
Area Total	10,175	4,154	945	217	201	147
Percent	(11.4)	(8.4)	(5.2)	(3.2)	(4.6)	(3.4)
AREA III (Mississippi Delta)						
Catahoula	1,576	857	239	91	63	96
Concordia	1,444	833	240	73	67	85
East Carroll	2,358	1,289	227	81	86	95
East Feliciana	1,354	776	188	56	43	28
Franklin	4,597	2,939	1,127	264	195	152
Madison	2,232	1,153	237	79	59	176
Morehouse	3,057	2,004	578	119	79	107
Point Coupee	2,222	1,319	552	255	129	135
Richland	3,735	2,318	752	169	134	107
Tensas	1,991	1,223	344	126	63	90
West Carroll	1,986	1,074	394	152	116	120
West Feliciana	1,011	529	290	70	39	27
Area Total	27,563	16,314	5,168	1,535	1,073	1,218
Percent	(30.9)	(33.2)	(28.3)	(22.7)	(24.7)	(28.0)
AREA IV (North and West Central Cut-Over Area)	1940	1950	1959	1969	1974	1978
Beauregard	369	242	77	57	37	49
Caldwell	486	257	61	34	21	23
Grant	633	342	82	28	17	12
Jackson	731	167	23	7	9	11
LaSalle	164	96	70	21	10	8
Sabine	981	240	126	9	18	21
Vernon	404	159	74	15	13	11
Winn	459	169	34	10	10	10
Area Total	4,227	1,672	547	181	135	145
Percent	(4.7)	(3.4)	(3.0)	(2.7)	(3.1)	(3.3)
AREA V (Southwest Rice Area)						
Acadia	2,534	1,723	931	317	191	235
Allen	395	209	88	65	47	56
Calcasieu	780	319	132	186	139	127
Cameron	480	146	50	58	47	53
Jefferson Davis	987	484	267	287	178	177
Vermilion	1,785	1,142	524	338	271	268
Area Total	6,961	4,023	1,992	1,251	873	916
Percent	(7.8)	(8.2)	(10.9)	(18.5)	(20.1)	(21.0)

(continued)

Table 6-B.—(Continued)

AREA VI (South Central La. Mixed Farming)						
Avoyelles	3,159	1,610	619	202	124	166
Evangeline	3,249	2,078	1,154	360	106	95
Lafayette	2,275	1,648	888	285	159	96
St. Landry	5,949	4,567	2,472	679	243	218
Area Total	14,632	9,903	5,133	1,526	632	575
Percent	(16.4)	(20.1)	(28.1)	(22.6)	(14.5)	(13.2)
AREA VII (The Sugar Bowl Area	1940	1950	1959	1969	1974	1978
Ascension	451	141	63	42	34	36
Assumption	201	82	82	94	60	55
Iberia	713	391	190	145	91	87
Iberville	406	227	129	117	83	94
Lafourche	478	294	192	162	117	145
St. James	166	77	42	66	57	39
St. John	81	32	13	19	22	17
St. Martin	1,705	1,267	539	237	123	93
St. Mary	169	125	90	78	56	43
Terrebonne	301	93	64	60	44	34
West Baton Rouge	340	152	95	33	32	28
Area Total	5,011	2,881	1,499	1,053	719	671
Percent	(5.6)	(5.8)	(8.2)	(15.6)	(16.5)	(15.4)
AREA VIII (The Florida Parishes)						
East Baton Rouge	699	310	80	87	54	54
Livingston	624	222	71	14	13	11
St. Helena	727	413	151	31	20	26
Tangipahoa	1,716	788	301	92	63	67
Washington	1,152	660	227	53	26	36
Area Total	4,918	2,393	830	277	176	194
Percent	(5.5)	(4.9)	(4.5)	(4.1)	(4.0)	(4.4)
AREA IX (New Orleans Truck and Fruit Area)						
Jefferson	114	52	18	17	13	18
Plaquemines	109	78	30	28	14	13
St. Bernard	53	25	5	7	3	5
St. Charles	125	67	20	34	42	25
St. Tammany	222	125	21	25	27	29
Area Total	623	347	94	111	99	90
Percent	(0.7)	(0.7)	(0.5)	(1.6)	(2.3)	(2.1)
Statewide Total	89,099	49,179	18,278	6,765	4,345	4,353
Percent*	(99.8)	(99.9)	(100.0)	(100.1)	(99.8)	(99.9)

*Deviations from 100 percent due to rounding error.
Compiled from *Census of Agriculture* for designated years.

Louisiana State University Agricultural Center, Alvin C. Harper, Chancellor
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Pasture Management Systems for Cow-Calf Production at Two Locations in Northeast Louisiana

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Beef cattle historically have been a part of the diversified farm in northeast Louisiana. In recent years spiraling land prices, high interest rates, and alternative uses for land have caused a reduction in cattle numbers in this area. Therefore, the beef production system must be intensified if it is to compete in areas with alternative land uses. A cow-calf project was initiated in 1974 at the Northeast Experiment Station, St. Joseph, and the Macon Ridge Branch Station, Winnsboro, to determine if a cow-calf unit could be maintained year-round on 1 acre of land at these locations. The Northeast Station is on the Mississippi River Alluvial flood plain, and the Macon Ridge Station is on Mississippi Terrace soils.

The objectives of the study were to compare pasture management systems for handling cow herds on a 12-month basis at each location, and to study the effect of each pasture management system on the weaning weight of the calves and the reproduction of the cows. Results of the 4-year study are presented here.

Experimental Procedure at St. Joseph

Pasture Systems

Four pasture management systems for cow-calf production were established on 80 acres of Sharkey clay soil at Northeast Louisiana Experiment Station. Each management system consisted of three pastures totaling 20 acres. These pasture systems are illustrated in Figure 1 and described as follows:

System I—one 8-acre pasture containing Kentucky 31 fescue and two 6-acre pastures containing common bermudagrass were established and overseeded with Nolins' Improved White Clover at the rate of 5 pounds per acre each fall.

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System II—20 acres of common bermudagrass divided into one 10-acre and two 5-acre pastures. Nolins' Improved White Clover was overseeded at the rate of 5 pounds per acre.

System III—cows rotationally grazed one 9-, one 5- and one 4-acre pasture containing common bermudagrass overseed each fall with ryegrass and clover. In addition, calves had access to two 1-acre pastures containing temporary forages planted on a prepared seedbed.

The following specific management system comparisons were made at St. Joseph: (1) creep grazing *vs.* no creep grazing (System III *vs.* System IV); (2) Fescue-clover *vs.* ryegrass-clover (System I *vs.* Systems III and IV); and (3) Clover alone *vs.* fescue-clover and ryegrass-clover (System II *vs.* Systems I, III and IV).

Figure 1.—Pasture Plan For Four Groups of Cows and Calves, Northeast Experiment Station, St. Joseph, La. (20 Cows With Calves and One Bull on 20 Acres)

	System I	
Fescue Claver (8 acres)	Common bermudagrass Claver (6 acres)	Camman bermudagrass Claver (6 acres)
	System II	
Camman bermudagrass Claver (10 acres)	Camman bermudagrass Claver (5 acres)	Camman bermudagrass Claver (5 acres)
	System III	
Common bermudagrass Claver Ryegrass (10 acres)	Common bermudagrass Clover Ryegrass (5 acres)	Common bermudagrass Clover Ryegrass (5 acres)
	System IV	
Camman bermudagrass Clover Ryegrass (9 acres)	Camman bermudagrass Claver Ryegrass (4 ocres)	Camman bermudagrass Claver Ryegrass (5 acres)
	Calf creep grazing Sudan-sorghum or wheat-ryegrass (2 acres)	

Pasture Management

Soil samples were taken on an annual basis to monitor pH, phosphorus and potassium levels. The experimental area was limed with 2 tons dolomitic limestone per acre in July, 1975. Systems I and II were fertilized each year with a total of 136 pounds of nitrogen per acre in two applications, usually in early summer after the clover matured and again in late summer. The 8-acre fescue pasture in System I received 67 pounds of nitrogen per acre in October and again in January. Systems III and IV received approximately 272 pounds of nitrogen per acre annually in four equal applications in April, July, November, and January.

Common bermudagrass pastures in Systems III and IV were sodseeded in the fall with a mixture of 20 pounds of ryegrass and 5 pounds of Nolins' Improved White Clover per acre using a conventional grain drill with single-disk openers spaced on 6-inch centers.

The 2 acres of temporary pasture used for calf creep grazing in System IV were seeded on a well prepared seedbed. Temporary winter pastures were seeded in early October with a mixture of 1 bushel of wheat and 20 pounds of ryegrass per acre. This same area was seeded with a sudan-sorghum hybrid at the rate of 30 pounds per acre in late May or early June each year.

Cattle Management

In December 1974, 80 grade, primiparous Angus cows were randomly divided into four groups of 20 each. Two Hereford bulls ware assigned to each group and rotated weekly during a 6-month breeding season (December 1 to June 1). The bulls were rotated yearly among herds, allowing each bull pair to be used in each herd for one breeding season during the 4 years.

Each group of cows was restructured on December 1 of each year. When possible, open cows were replaced with pregnant ''extra'' cows from another cattle herd maintained for that purpose. Cows that had lost a calf or cows that had some physical defect were culled and replaced. Replacement cows were used only to maintain equal stocking rates and were not used in computing reproductive efficiencies or weaning weights.

Cows and calves were vaccinated annually for blackleg, malignant edema, red water, leptosporosis and anthrax. All cows were given an anthelmintic in the spring to control internal parasites. Spraying was used as needed to control hornflies and lice. Salt and minerals were supplied free choice.

All calves were weighed within two weeks of 205 days of age and weighed again and weaned at approximately 9 months of age. Cows were weighed when calves were weaned.

Analytical Methods

Least squares analysis of variance procedures with unequal sub-class numbers were used to test for differences among the four pasture-management systems. Linear contrasts were made among systems when appropriate.

Results and Discussion

Hay Production and Consumption

Excess forage produced in each pasture system was baled in large round bales (approximately 1,000 pounds) and an attempt was made to feed the hay to cows in the treatments where it was produced. Hay production and consumption by systems during the study are shown in Table 1.

Table 1.—Hay Production and Consumption, 4-Year Average, St. Joseph

Pasture system	Hay produced (tons)	Hay fed (tons)	Difference (tons)	Hay fed (days)	Total grazing (days)
I	2.6	23.1	−20.5	109	256
II	14.8	24.3	− 9.5	111	254
III	10.4	20.3	− 9.9	97	268
IV	8.1	20.4	−12.3	97	268

System I produced the smallest amount of hay (2.6 tons) and had the largest deficiency of hay (−20.5 tons) of any system. This is because only 12 acres of the system contained common bermudagrass to produce hay and the other 8 acres contained fescue from which no hay was harvested.

Cattle in System II consumed the most hay (24.3 tons) for the longest period of time (111 days). This system also produced the most hay (14.8 tons) and had the smallest deficiency of hay.

Cattle in Systems III and IV consumed the smallest amount of hay (20.3 and 20.4 tons, respectively) and required feeding the least number of days (97). System III produced slightly more hay than System IV because 2 acres of System IV were used as a calf creep grazing area and therefore produced no hay. Sod-seeded ryegrass in these systems retarded bermudagrass growth in the spring when it was allowed to grow for hay production.

Cattle Performance

Reproductive performance, calving interval, and cow weight when the calves were weaned for the 4 years of the study are shown in Table 2.

Weaning rate was not significantly influenced by pasture management system. Weaning rate is defined as the ratio of calves weaned to the total number of cows exposed to the bulls during the 6-month breeding season. Weaning rates ranged from 86 percent for cows in System III containing the sod-seeded ryegrass to 81 percent for cows on System I containing 8 acres of fescue. In general, cattle in systems containing ryegrass had higher weaning rates than cattle in the other treatments.

Table 2.—Least Squares Means For Weaning Rate, Calving Interval, and Cow Weight in the Four Pasture Management Systems, St. Joseph, 1975-79

Pasture system	No. of cows	Weaning rate (%)	Calving interval (days)	Cow weight[2] (pounds)
I	84	81 ± 0.04	387 ± 6.4	944 ± 11.9
II	84	82 ± 0.04	387 ± 6.3	931 ± 11.8
III	85	86 ± 0.04	375 ± 6.0	953 ± 11.8
IV	83	84 ± 0.04	390 ± 6.4	903 ± 12.1
Contrast:				
III vs. IV		N.S.[3]	N.S.	**[4]
I vs. III, IV		N.S.	N.S.	N.S.
II vs. I, III, IV		N.S.	N.S.	N.S.

[1] Weaning Rate = a ratio of the number of calves weaned to the number of cows exposed to the bull ± standard error.

[2] Cow weight when calves were weaned ± standard error.

[3] No significant difference ($P > .05$).

[4] Significant at $P < .01$ level.

Pasture management system also had no effect on calving interval. The calving interval ranged from 375 days for System III to 390 days for System IV.

Pasture management system had a highly significant effect on cow weight when the calves were weaned. Cows on the sod-seeded ryegrass (System III) were significiantly heavier than cows in System IV containing the 2-acre calf creep grazing area (953 pounds vs. 903 pounds) (Table 2). It must be noted that the cows in System IV grazed only 18 acres whereas the cows in other systems grazed 20 acres. A higher stocking rate could explain why cows in this treatment were lighter.

Pasture management system had a highly significant effect on 7-month and adjusted 205-day calf weights (Table 3). Calves produced in either of the sod-seeded ryegrass systems (III and IV) were heavier than calves produced in the system containing fescue (System I). However, at actual weaning time (9 months) the calves on the sod-seeded ryegrass treatments were not significantly heavier than the calves produced on the other treatments. Most of the calves were born in the fall and weighed in early spring at 7 months of age. Therefore calves on the sod-seeded ryegrass treatments were heavier at this time because they had been on a higher level of nutrition during the winter and spring months. Calves on the fescue treatment and the common bermudagrass-clover treatment (Systems I and II) were able to make compensatory gains and therefore were similar in weight to the sod-seeded ryegrass treatment calves at 9 months of age.

There was no significant difference between the weaning weights of calves that had access to the creep grazing and the weaning weights of those that did not. It should be pointed out that the creep grazing areas were at the opposite ends of the pastures from the loafing and watering facilities which

Table 3.—Least Squares Means For 7-Month, Adjusted 205-Day, and 9-Month Weaning Weight of Calves Produced From Four Pasture Management Systems, St. Joseph, 1975-79

Pasture system	No. of calves	7-month weight[1]	205-day adjusted wt.[2]	9-manth weaning wt.[3]
		------------------	pounds	------------------
I	60	370 ± 5.9	353 ± 5.6	444 ± 6.0
II	61	373 ± 5.4	354 ± 5.1	450 ± 5.5
III	60	390 ± 5.5	372 ± 5.3	460 ± 5.7
IV	55	388 ± 5.9	370 ± 5.6	454 ± 6.0
Contrast:				
III vs. IV		N.S.[4]	N.S.	N.S.
I vs. III, IV		**[5]	**	N.S.
II vs. I, III, IV		N.S.	N.S.	N.S.

[1] 7-manth weight = actual mean weight af calves at 7 manths ± standard error.

[2] 205-day adjusted weight = mean weight adjusted for oge af dam, age af calf, and sex (steer basis) ± standard error.

[3] 9-manth weaning weight = actual mean weight af calves when weaned at 9 manths ± standard error.

[4] No significant difference ($P > .05$).

[5] Significant at the $P < .01$ level.

the brood cows utilized, and there seemed to be some reluctance for the young calves to journey that far from their dams to graze.

Weaning weights of calves on clover (System II) were not significantly different from the average of the other systems containing winter forages. Excellent clover was usually available in the pastures not seeded with ryegrass from late February until June.

Experimental Procedure at Winnsboro

Pasture Systems

Four pasture management systems for cow-calf production were established on 96 acres of loessial soil at Macon Ridge Branch Station classified as a Grenada or Oliver silt loam. Each management system consisted of three pastures totaling 24 acres. These pasture systems are illustrated in Figure 2 and described as follows:

System I—pasture System I consisted of 24 acres of common bermudagrass divided into three 8-acre pastures which were overseeded each fall with ryegrass and clover.

System II—this system consisted of two 8-acre and one 6-acre pasture containing common bermudagrass overseeded each fall with ryegrass and clover. In addition, calves had access to a 2-acre pasture containing temporary forages planted on a prepared seedbed.

System III—three 8-acre pastures containing common bermudagrass overseeded each fall with 20 pounds of ryegrass provided forages for the cow herd in System III.

Figure 2.—Pasture Plan For Four Groups of Cows and Calves, Macon Ridge Station, Winnsboro, La. (24 Cows With Calves and One Bull On 24 Acres)

System I		
Common bermudagrass Clover Ryegrass (8 acres)	Common bermudagrass Clover Ryegrass (8 acres)	Common bermudagrass Clover Ryegrass (8 acres)
System II		
Common bermudagrass Clover Ryegrass (8 acres)	Common bermudagrass Clover Ryegrass (6 acres) ------------------ Calf creep grazing Millet or wheat-ryegrass (2 acres)	Common bermudagrass Clover Ryegrass (8 acres)
System III		
Common bermudagrass Ryegrass (8 acres)	Common bermudagrass Ryegrass (8 acres)	Common bermudagrass Ryegrass (8 acres)
System IV		
Coastal bermudagrass Clover Ryegrass (8 acres)	Coastal bermudagrass Clover Ryegrass (8 acres)	Coastal bermudagrass Clover Ryegrass (8 acres)

System IV—pasture System IV consisted of 24 acres of Coastal bermudagrass divided into three 8-acre pastures which were overseeded each fall with ryegrass and clover.

The following specific (non-independent) comparisons were made in the experiment conducted at this location: (1) Creep grazing *vs.* no creep grazing on common bermudagrass (System II *vs.* System I); (2) Common bermudagrass *vs.* Coastal bermudagrass (System I *vs.* System IV); and (3) Ryegrass *vs.* ryegrass-clover (System III *vs.* Systems I, II, and IV).

Pasture Management

The experimental area was limed with 2 tons dolomitic limestone per acre in the summer of 1975, while 400 pounds of 8-24-24 was applied each fall of 1976 and 1977. All pastures received approximately 272 pounds of nitrogen per acre annually in four equal applications in April, July, November and January.

All pastures were sod-seeded each fall with 20 pounds of ryegrass using a conventional grain drill with double-disk openers. Pastures in Systems I, II, and IV were also seeded each fall with 5 pounds of Nolins' Improved White Clover per acre.

The 2 acres of temporary pasture used for calf creep grazing in System II was seeded on a prepared seedbed. Temporary winter pastures were seeded in early October with a mixture of 1 bushel of wheat and 20 pounds of ryegrass per acre. This same area was seeded with millet at the rate of 30 pounds per acre in late May or early June each year.

Cattle Management

Ninety-six F-1 Brahman x Hereford cows ranging in age from 4 to 14 years were randomly divided into four groups. Angus bulls were exposed to each group of cows.

These animals were managed the same as the cattle at the Northeast Experiment Station.

Results and Discussion

Hay Production and Consumption

Hay production and consumption levels for each system during the study are shown in Table 4. In general, cattle in all the systems required more winter hay supplementation than was produced from that area during the summer. All systems were overseeded with ryegrass and the majority of hay produced at this location came from ryegrass. Usually the amount and distribution of rainfall was inadequate for high forage yields during the summer months. It is possible that allowing the ryegrass to make adequate growth for hay also depressed the growth of the bermudagrass.

Table 4.—Hay Production and Consumption, 2-Year Average, Winnsboro

Pasture system	Hay produced (tons)	Hay fed (tans)	Difference (tans)	Hay fed (days)	Tatal grazing (days)
I	18	31.5	−13.5	132	233
II	13	31.5	−18.5	132	233
III	19	31.5	−12.5	132	233
IV	18	31.5	−13.5	132	233

Amounts of hay produced and consumed in each of the pasture management systems were similar. Cattle in all the systems had to be supplemented with hay from approximately November 4 to March 15 each year (Table 4). Ryegrass was the major forage in all systems from March 15 to June 1. Bermudagrass was the predominant forage in all the systems from June through October.

Clover was included in all systems except System III. Some difficulty occurred in managing the ryegrass-clover mixtures for optimum forage production and utilization. The pastures were fertilized heavily with nitrogen, and grass was permitted to grow for hay production, therefore, clover usually made up a very small portion of the forage mixture.

The Coastal bermudagrass in System IV was sprigged in March, 1974 when the weather was extremely dry. A complete ground cover was never obtained during the course of the study. This may explain why the cattle in this system did not perform as well as in the other systems.

Cattle Performance

Reproductive performance, calving intervals, and cow weights for the four systems at the Macon Ridge location are shown in Table 5.

Table 5.—Least Squares Means For Weaning Rate, Calving Interval, and Cow Weight in the Four Pasture Management Systems, Winnsboro, 1975-79

Pasture system	No. of cows	Weaning rate[1] (%)	Calving interval (days)	Cow weight[2] (pounds)
I	94	78 ± 0.04	400 ± 8.3	1025 ± 16.6
II	93	79 ± 0.04	398 ± 8.7	1054 ± 16.7
III	96	75 ± 0.04	402 ± 12.9	1050 ± 17.0
IV	96	66 ± 0.04	448 ± 18.0	1016 ± 17.8
Contrast:				
I vs. II		N.S.[3]	N.S.	N.S.
I vs. IV		*[4]	*	N.S.
III vs. I, II, IV		N.S.	N.S.	N.S.

[1] Weaning rate = a ratio of the number of calves weaned to the number of cows exposed to the bull ± standard error.

[2] Mean cow weight when calves were weaned ± standard error.

[3] No significant difference ($P > .05$).

[4] Significant at $P < .05$ level.

Pasture management system had a significant effect on weaning rate. The weaning rate for cows on System I containing common bermudagrass, clover and ryegrass was 78 percent compared to 66 percent for cows on Coastal bermudagrass, clover, and ryegrass. The cattle were bred from December 1 to June 1 and therefore the variety of bermudagrass should not have been a factor influencing this parameter. The absence of clover or the presence of a 2-acre creep grazing area had no influence on weaning rates.

Calving interval ranged from 448 days in System IV containing Coastal bermudagrass to 398 days for System II containing the calf creep grazing area. Calving intervals in all systems were too long and probably reflect a nutritional stress due to the shortage of forage during the first half of the breeding season.

None of the systems had any influence on cow weight at the time the calves were weaned. The heaviest cows were in System II containing the creep grazing area and the lightest cows were in System IV containing the Coastal bermudagrass.

Pasture management had a highly significant effect on 7-month, 205-day adjusted, and 9-month weaning weight of calves (Table 6). Calves in System II were 71 pounds heavier than calves in System I when they were weaned at 9 months of age.

Variety of bermudagrass had no effect on calf weaning weight. Calves produced in the system containing common bermudagrass were as heavy as calves produced in the system containing Coastal (System I *vs*. System IV). Also, clover had no effect on weaning weight (System III *vs*. System I).

Table 6.—Least Squares Means For 7-Month, Adjusted 205-Day, and 9-Month Weaning Weight of Calves Produced From Four Pasture Management Systems, Winnsboro, 1975-79

Pasture system	No. of calves	7-month weight[1]	205-day adjusted wt.[2]	9-month weaning wt.[3]
			-pounds-	
I	63	389 ± 6.8	370 ± 6.9	462 ± 7.0
II	62	441 ± 6.8	418 ± 6.9	533 ± 7.0
III	61	419 ± 7.1	397 ± 7.2	506 ± 7.2
IV	55	408 ± 7.1	386 ± 7.2	475 ± 7.2
Contrast:				
I *vs*. II		**[4]	**	**
I *vs*. IV		N.S.[5]	N.S.	N.S.
III *vs*. I, II, IV		N.S.	N.S.	N.S.

[1] 7-month weight = actual mean weight of calves at 7 months ± standard error.

[2] 205-day adjusted weight = mean weight adjusted for age of dam, age of calf, and sex (steer basis) ± standard error.

[3] 9-month weaning weight = actual mean weight of calves when weaned at 9 months ± standard error.

[4] Significant at the $P<.01$ level.

[5] No significant difference ($P>.05$).

Economic Analysis

The budgets used to compare pasture management systems incorporate the average level of inputs and production per cow for 1976 through 1980 using the actual percent calf crop weaned and the average weaning weight of each system. Prices used for estimating the costs are 1981 projected prices which were higher than actual costs incurred during the study. However, the relative differences in production cost for each system will remain the same. No returns are presented in any of the budgets. Herd replacements were not maintained within the pasture systems. For purposes of calculating breakeven prices required to recover production costs, the assumption was made that the value of cull cows was sufficient to purchase replacement animals.

More hay was required than produced within the pasture systems, therefore two separate items are included in the budgets for hay fed. One included only the costs for harvesting and feeding hay for the quantity derived from within the pasture system. The other accounted for hay required from outside the pasture system with price based on cost of producing and harvesting hay with a 4-ton yield per acre. Thus, the production costs are directly comparable among the systems.

Northeast Experiment Station

Average annual pasture costs per acre at the Northeast Experiment Station were $104.71, $105.38, $149.55, and $152.04 for Systems I, II, III, and IV, respectively. Detailed cost budgets for pasture production and hay harvesting are shown in Appendix Tables 1 through 8.

Total annual specified costs of maintaining a cow and producing a calf were lowest with Systems I and II at $371.06 and $364.65, respectively, and highest with Systems III and IV at $402.48 and $407.95, respectively. In general, more pounds of calf were produced per cow with systems containing ryegrass, but at a higher cost. Total specified costs were lowest with System II at $98.82 per hundredweight marketable calf produced. Costs with Systems I and III during the 4-year study were $103.07 and $101.64, respectively, per hundredweight of marketable calf. Costs were highest with System IV at $107.07 per hundredweight of calf. Breakeven selling prices required to recover total specified costs and variable cost for five production levels for each system are shown in Table 7. Detailed costs of production for the systems are shown in Appendix Tables 9 through 12.

Table 7.—Breakeven Selling Prices for Weanling Calves Produced from Various Pasture Management Systems, St. Joseph, 1975-79[1]

Pasture systems	Production level per cow				
	−20%	−10%	Four-year average	+10%	+20%
	Dollars per hundredweight				
	Prices required to recover total specified costs[2]				
I	128.84	114.52	103.07	93.70	85.89
II	123.53	109.80	98.82	89.84	82.35
III	127.05	112.93	101.64	92.40	84.70
IV	133.84	118.97	107.07	97.34	89.23
	Prices required to recover variable costs[3]				
I	69.77	62.02	55.82	50.74	46.52
II	66.39	59.01	53.11	48.28	44.26
III	74.19	65.95	59.35	53.96	49.46
IV	79.05	70.27	63.24	57.49	52.70

[1] Based on 1981 prices for production inputs.

[2] Does not include land and management.

[3] Includes cash costs plus labor.

Macon Ridge Branch

Average annual pasture cost per acre at the Macon Ridge Branch were $149.55, $151.63, $139.55, and $149.55 for Systems I, II, III, and IV, respectively. Detailed cost budgets for pasture production and hay harvesting are shown in Appendix Tables 13 through 19.

Total annual specified costs of maintaining a cow and producing a calf were lowest for the system without clover (System III at $390.58) and highest for the system containing the calf creep grazing area (System II at $407.18). The total annual specified costs were the same for Systems I and IV at $401.77. However, more pounds of marketable calf were produced in System II and at a lower cost per hundredweight (421 pounds at $96.72 per cwt.). Costs with Systems I and III during the 4-year study were $111.60 and $102.78, respectively, per hundredweight of calf. Costs were highest with System IV at $127.95 per hundredweight of calf. Breakeven selling prices required to recover total specified costs and variable costs for five production levels for each system are shown in Table 8. Detailed costs of production for each of the systems are shown in Appendix Tables 20 and 23.

Table 8.—Breakeven Selling Prices for Weanling Calves Produced from Various Pasture Management Systems, Winnsboro, 1975-79[1]

Pasture systems	Production level per caw −20%	−10%	Four-year average	+10%	+20%
	Dollars per hundredweight				
	Prices required to recover total specified costs[2]				
I	139.50	124.00	111.60	101.46	93.00
II	120.90	107.46	96.72	87.92	80.60
III	128.48	114.20	102.78	93.44	85.65
IV	159.94	142.17	127.95	116.32	106.63
	Prices required to recover variable costs[3]				
I	82.43	73.27	65.94	59.95	54.95
II	72.35	64.31	57.88	52.62	48.23
III	74.48	66.20	59.58	54.17	49.65
IV	94.50	84.00	75.60	68.73	63.00

[1] Based on 1981 prices for production inputs.

[2] Does not include land and management.

[3] Includes cash costs plus labor.

Conclusions

Based on the prevailing conditions of this pasture management study, the following conclusions appear to be valid: (1) One acre of land did not produce enough forage to maintain one beef cow-calf unit year-round in any of the systems tested at either location; (2) Management system had no significant effect on reproductive performance as measured by weaning percent or calving interval at the Northeast Experiment Station; however, at the Macon Ridge Branch Station there was a highly significant difference in reproductive performance. Cows in the common bermudagrass-clover plus ryegrass system had a higher weaning percent and shorter calving interval than cows in Coastal bermudagrass-clover plus ryegrass system; (3) Calves produced in either of the sod-seeded ryegrass systems (III and IV) at the Northeast Experiment Station were heavier ($P<.01$) at 7 months and had heavier adjusted 205-day weights than calves produced in the fescue-clover system (I); (4) Creep-grazing calves at the Macon Ridge Station resulted in heavier 7-month, 205-day, and 9-month weaning weights than calves produced in common bermudagrass-clover plus ryegrass programs without the creep grazing; (5) In general, costs per hundredweight of calves produced were higher at the Winnsboro location than at the St. Joseph location. Total specified costs and variable costs per hundredweight averaged 7 percent and 12 percent higher, respectively, at the Winnsboro location compared to the St. Joseph location; (6) Based on average performance levels for the 4-year period and 1981 prices, none of the systems would have provided sufficient returns to recover all costs. However, all systems except System IV at Winnsboro would have provided returns above labor and cash costs thus providing some return to partially defray fixed costs associated with the beef cattle enterprise.

Appendix Table 1.—Equipment, Fertilizer, Seed, and Labor Costs for 20-Acre Pasture Units, Northeast Experiment Station, St. Joseph, 1976-1980

Pasture system	Fescue + Clover	Common bermudagrass + Clover	Common bermudagrass sodseeded ryegrass + clover	Prepared seedbed wheat + ryegrass	Prepared seedbed sudan sorghum	Fixed cost	Annual cost for 20 acres	Average annual cost/A
I[1]	$663.20	$1009.92	—	—	—	$421.00	$2094.12	$104.71
II[2]	—	1683.20	—	—	—	424.40	2107.60	105.38
III[3]	—	—	$2536.40	—	—	454.60	2991.00	149.55
IV[4]	—	—	2282.76	$173.98	$150.68	433.40	3040.82	152.04

[1] 8 acres fescue + clover and 12 acres common bermudagrass + clover.

[2] 20 acres common bermudagrass + clover.

[3] 20 acres common bermudagrass + clover + sodseeded ryegrass.

[4] 18 acres common bermudagrass + clover + sodseeded ryegrass + 2 acres prepared seedbed calf-creep area.

Appendix Table 2.—Estimated Costs Per Acre for Bermuda + Clover, Northeast Experiment Station, St. Joseph, 1976-80

Item	Cost per acre
Variable costs	
Lime (2 tons @ $24/ton ÷ 4 years)	12.00
Nitrogen (144 lbs. @ $.24)	34.56
Phosphate (24 lbs. @ $.30)	7.20
Potash (24 lbs. @ $.13)	3.12
Clover seed (5 lbs. @ $2.00)	10.00
Machinery (fuel, lube, repair)	2.43
Tractor (fuel, lube, repair)	4.06
Labor (tractor & machinery) (2.36 hrs. @ $4.00)	9.42
Interest on operating capital ($10.56 @ 13%)	1.37
Total specified variable costs	84.16
Fixed costs	
Machinery	5.34
Tractors	2.53
Prorated established cost ($133.50/acre ÷ 10 years)	13.35
Total specified fixed costs	21.22
Total specified costs	105.38

Appendix Table 3.—Estimated Costs Per Acre for Fescue + Clover, Northeast Experiment Station, St. Joseph, 1976-80

Item	Cost per acre
Variable costs	
Lime (2 tons @ $24/ton ÷ 4 years)	12.00
Nitrogen (142 lbs. @ $.24)	34.08
Phosphate (24 lbs. @ $.30)	7.20
Potash (24 lbs. @ $.13)	3.12
Clover seed (5 lbs. @ $2.00)	10.00
Machinery (fuel, lube, repair)	2.38
Tractor (fuel, lube, repair)	3.51
Labor (tractor & machinery) (2.22 hrs. @ $4.00)	8.89
Interest on operating capital ($13.20 @ 13%)	1.72
Total specified variable costs	82.90
Fixed costs	
Machinery	5.25
Tractors	2.20
Prorated established cost ($133.50/acre ÷ 10 years)	13.35
Total specified fixed costs	20.80
Total specified costs	103.70

Appendix Table 4.—Estimated Costs Per Acre for Bermuda + Ryegrass + Clover, Northeast Experiment Station, St. Joseph, 1976-80

Item	Cost per acre
Variable costs	
Lime (2 tons @ $24/ton ÷ 4 years)	12.00
Nitrogen (280 lbs. @ $.24)	67.20
Phosphate (24 lbs. @ $.30)	7.20
Potash (24 lbs. @ $.13)	3.12
Clover seed (5 lbs. @ $2.00)	10.00
Ryegrass seed (20 lbs. @ $.16)	3.20
Machinery (fuel, lube, repair)	2.78
Tractor (fuel, lube, repair)	5.43
Labor (tractor & machinery) (2.62 hrs. @ $4.00)	10.49
Interest on operating capital ($41.57 @ 13%)	5.40
Total specified variable costs	126.82
Fixed costs	
Machinery	5.99
Tractors	3.39
Prorated established cost ($133.50/acre ÷ 10 years)	13.35
Total specified fixed costs	22.73
Total specified costs	149.55

Appendix Table 5.—Estimated Costs Per Acre of Prepared Seedbed for Wheat + Ryegrass, Northeast Experiment Station, St. Joseph, 1976-80

Item	Cost per acre
Variable costs	
Lime (1 ton @ $24/ton ÷ 4 years)	6.00
Nitrogen (144 lbs. @ $.24)	33.60
Phosphate (12 lbs. @ $.30)	3.60
Potash (12 lbs. @ $.13)	1.56
Wheat seed (1 bu. @ $12)	12.00
Ryegrass seed (20 lbs. @ $.16)	3.20
Machinery (fuel, lube, repair)	3.95
Tractor (fuel, lube, repair)	7.16
Labor (tractor & machinery) (2.85 hrs. @ $4.00)	11.42
Interest on operating capital ($34.66 @ 13%)	4.51
Total specified variable costs	86.99
Fixed costs	
Machinery	7.57
Tractors	4.54
Total specified fixed costs	12.10
Total specified costs	99.10

Appendix Table 6.—Estimated Costs Per Acre of Prepared Seedbed for Sudan-sorghum, Northeast Experiment Station, St. Joseph, 1976-80

Item	Cost per acre
Variable costs	
Lime (1 ton @ $24/ton ÷ 4 years)	6.00
Nitrogen (140 lbs. @ $.24)	33.60
Phosphate (12 lbs. @ $.30)	3.60
Potash (12 lbs. @ $.13)	1.56
Sudan sorghum seed (30 lbs. @ $.18)	5.40
Machinery (fuel, lube, repair)	3.95
Tractor (fuel, lube, repair)	7.16
Labor (tractor & machinery) (2.85 hrs. @ $4.00)	11.42
Interest on operating capital ($20.37 @ 13%)	2.65
Total specified variable costs	75.34
Fixed costs	
Machinery	7.57
Tractors	4.54
Total specified fixed costs	12.10
Total specified costs	87.44

Appendix Table 7.—Estimated Hay Harvesting Costs for 1-Ton Yield Per Acre, Half Ton Per Cutting, Northeast Experiment Station, St. Joseph, 1976-80

Item	Cost per acre
Variable costs	
Harvest costs	
Twine	.38
Machinery (fuel, lube, repair)	5.67
Tractor (fuel, lube, repair)	12.13
Labor (tractor & machinery) (2.40 hrs. @ $4.00)	9.61
Total specified variable costs	27.79
Fixed costs	
Machinery	6.42
Tractors	7.69
Total specified fixed costs	14.10
Total specified costs	41.90

Appendix Table 8.—Estimated Hay Production Costs for 4-Ton Yield Per Acre, Northeast Experiment Station, St. Joseph, 1976-80

Item	Cast per acre
Variable costs	
Preharvest	
Lime (320 lbs. @ $24/tan)	3.84
Nitrogen (180 lbs. @ $24)	43.10
Phosphate (32 lbs. @ $30)	9.57
Patash (63 lbs. @ $13)	8.13
Machinery (fuel, lube, repair)	1.99
Labar (tractar & machinery) (1.52 hrs. @ $4.00)	6.07
Interest an operating capital ($25.14 @ 13%)	3.27
Subtatal, preharvest	75.97
Harvest casts	
Twine (4 lbs. @ $.38)	1.52
Machinery (fuel, lube, repair)	12.07
Tractar (fuel, lube, repair)	42.06
Labar (tractar & machinery) (7.42 hrs. @ $4.00)	29.66
Subtatal horvest	85.31
Tatal specified variable costs	161.28
Fixed costs	
Machinery	19.07
Tractors	26.85
Prarated established cost ($133.50 ÷ 10 years)	13.35
Land (net rent)	15.00
Tatal specified fixed casts	74.27
Tatal specified casts	235.55

Appendix Table 9.—Estimated Costs for Pasture System I, Northeast Experiment Station, St. Joseph, 1976-80

Item	Amount	
	20 cows	per cow
	------------Dollars------------	
Variable costs		
Bermuda + clover (12 acres @ $84.16)	1009.92	50.00
Fescue + clover (8 acres @ $82.90)	663.20	33.16
Hay produced (2.6 tons @ $27.79)	72.25	5.61
Hay purchased (20.5 tons @ $40.32)	826.56	41.33
Protein supplement (11 cwt. @ $3.10)	34.10	1.71
Medication (20 head @ $9.50)	190.00	9.50
Minerals (4 cwt. @ $9.00)	36.00	1.80
Tractor (fuel, lube, repair)	14.72	.74
Machinery (fuel, lube, repair)	23.11	1.16
Equipment (fuel, lube, repair)	114.18	5.71
Labor		
Tractor and machinery (48.5 hrs. @ $4.00)	194.00	9.70
Equipment (30 hrs. @ $4.00)	120.00	6.00
Livestock (145.25 hrs. @ $4.00)	581.00	29.05
Interest on operating capital ($1075.59 @ 13%)	139.83	6.98
Total specified variable costs	4018.87	200.95
Fixed costs		
Pastures (20 acres @ $21.05)	421.00	21.05
Hay produced (2.60 tons @ $14.10)	36.66	1.83
Hay purchased (20.50 tons @ $18.57)	380.69	19.03
Interest on livestock capital ($14,999.99 @ 13%)	1950.00	97.50
Interest on other equipment ($1794.00 @ 13%)	233.22	11.66
Depreciation on other equipment	258.40	12.92
Other fixed cost, machinery & equipment	122.33	6.12
Total specified fixed costs	3402.30	170.11
Total specified costs	7421.17	371.06
Pounds calf produced	7200	360
Total specified costs per hundredweight		103.07

Appendix Table 10.—Estimated Costs for Pasture System II, Northeast Experiment Station, St. Joseph, 1976-80

Item	Amount 20 cows	 per cow
	------Dollars------	
Variable costs		
Bermuda + clover (20 acres @ $84.16)	1683.20	84.16
Hay produced (14.80 tons @ $27.79)	411.29	20.56
Hay purchased (9.50 tons @ $40.32)	383.04	19.15
Protein supplement (3.10 cwt. @ $11.00)	34.10	1.71
Medication (20 head @ $9.50)	190.00	9.50
Minerals (4 cwt. @ $9.00)	36.00	1.80
Tractor (fuel, lube, repair)	14.72	.74
Machinery (fuel, lube, repair)	23.11	1.16
Equipment (fuel, lube, repair)	114.18	5.71
Labor		
Tractor and machinery (48.50 hrs. @ $4.00)	194.00	9.70
Equipment (30 hrs. @ $4.00)	120.00	6.00
Livestock (145.25 hrs. @ $4.00)	581.00	29.05
Interest on operating capital ($1044.13 @ 13%)	135.74	6.74
Total specified variable costs	3920.38	195.98
Fixed costs		
Pastures (20 acres @ $21.22)	424.40	21.33
Hay produced (14.80 tons @ $14.10)	208.68	10.43
Hay purchased (9.50 tons @ $18.57)	176.42	8.82
Interest on livestock capital ($14,999.99 @ 13%)	1950.00	97.50
Interest on other equipment ($1794.00 @ 13%)	233.22	11.66
Depreciation on other equipment	258.40	12.92
Other fixed cost, machinery & equipment	122.33	6.12
Total specified fixed costs	3373.45	168.67
Total specified costs	7293.82	364.65
Pounds calf produced	7380	369
Total specified costs per hundredweight		98.82

Appendix Table 11.—Estimated Costs for Pasture System III, Northeast Experiment Station, St. Joseph, 1976-80

Item	Amount	
	20 cows	per cow
	--------------Dollars--------------	
Variable costs		
Bermuda + clover + ryegrass (20 acres@ $126.82)	2536.40	126.82
Hay produced (10.40 tons@ $27.79)	289.02	14.51
Hay purchased (9.90 tons@ $40.32)	399.17	19.96
Protein supplement (3.10 cwt. @ $11.00)	34.10	1.71
Medication (20 head@ $9.50)	190.00	9.50
Minerals (4 cwt. @ $9.00)	36.00	1.80
Tractor (fuel, lube, repair)	14.72	.74
Machinery (fuel, lube, repair)	23.11	1.16
Equipment (fuel, lube, repair)	114.18	5.71
Labor		
Tractor and machinery (48.50 hrs. @ $4.00)	194.00	9.70
Equipment (30 hrs. @ $4.00)	120.00	6.00
Livestock (145.25 hrs. @ $4.00)	581.00	29.05
Interest on operating capital ($1293.14@ 13%)	168.11	8.38
Total specified variable costs	4699.80	235.04
Fixed costs		
Pastures (20 acres@ $22.73)	454.60	22.73
Hay produced (10.40 tons@ $14.10)	146.64	7.33
Hay purchased (9.90 tons@ $18.57)	183.84	9.19
Interest on livestock capital ($14,999.99@ 13%)	1950.00	97.50
Interest on other equipment ($1794.00@ 13%)	233.22	11.66
Depreciation on other equipment	258.40	11.66
Other fixed cost, machinery & equipment	122.33	6.11
Total specified fixed costs	3349.03	167.44
Total specified costs	8048.83	402.48
Pounds calf produced	7920	396
Total specified costs per hundredweight		101.64

Appendix Table 12.—Estimated Costs for Pasture System IV, Northeast Experiment Station, St. Joseph, 1976-80

Item	Amount	
	20 cows	per cow
	------------Dollars------------	
Variable costs		
Bermuda + clover + ryegrass (18 acres @ $126.82)	2282.76	114.14
Calf Creep		
Ryegrass (2 acres @ $86.99)	173.98	8.70
Sudan-sorghum (2 acres @ $75.35)	150.68	7.53
Hay produced (8.10 tons @ $27.79)	225.10	11.25
Hay purchased (12.30 tons @ $40.32)	495.94	24.80
Protein supplement (3.10 cwt. @ $11.00)	34.10	1.71
Medication (20 head @ $9.50)	190.00	9.50
Minerals (4 cwt. @ $9.00)	36.00	1.80
Tractor (fuel, lube, repair)	14.72	.74
Machinery (fuel, lube, repair)	23.11	1.16
Equipment (fuel, lube, repair)	114.18	5.71
Labor		
Tractor and machinery (48.50 hrs. @ $4.00)	194.00	9.70
Equipment (30 hrs. @ $4.00)	120.00	6.00
Livestock (145.25 hrs. @ $4.00)	581.00	29.05
Interest on operating capital ($1412.82 @ 13%)	183.67	9.16
Total specified variable costs	4819.23	240.95
Fixed costs		
Pastures (20 acres @ $21.67)	433.40	21.67
Hay produced (8.10 tons @ $14.10)	114.21	5.71
Hay purchased (12.30 tons @ $18.57)	228.41	11.42
Interest on livestock capital ($14,999.99 @ 13%)	1950.00	97.50
Interest on other equipment ($1794.00 @ 13%)	233.22	11.66
Depreciation on other equipment	258.40	12.92
Other fixed cost, machinery & equipment	122.33	6.11
Total specified fixed costs	3339.97	167.00
Total specified costs	8159.20	407.95
Pounds calf produced	7620	381
Total specified costs per hundredweight		107.07

Appendix Table 13.—Equipment, Fertilizer, Seed, and Labor Costs for 24-Acre Pasture Units, Macon Ridge Branch Station, Winnsboro, 1976-1980

Pasture system	Common bermudagrass + Sodseeded ryegrass + Clover	Common bermudagrass + Sodseeded ryegrass	Coastal bermudagrass + Sodseeded ryegrass + Clover	Prepared seedbed wheat + Ryegrass	Prepared seedbed millet	Fixed cost	Annual cost for 24 acres	Average annual cost/A
I[1]	$3043.68	—	—	—	—	$545.52	$3589.20	$149.55
II[2]	2790.04	—	—	$173.98	$150.68	524.40	3639.10	151.63
III[3]	—	$2803.68				545.52	3349.20	139.55
IV[4]	—	—	$3043.68			545.52	3589.20	149.55

[1] 24 acres common bermudagrass + sodseeded ryegrass + clover.

[2] 24 acres common bermudagrass + sodseeded ryegrass + clover + 2 acres prepared seedbed calf-creep area.

[3] 24 acres common bermudagrass + sodseeded ryegrass.

[4] 24 acres coastal bermudagrass + sodseeded ryegrass + clover.

Appendix Table 14.—Estimated Costs Per Acre for Bermuda + Clover + Ryegrass, Macon Ridge Branch Station, Winnsboro, 1976-80

Item	Cost per acre
Variable costs	
Lime (2 tons@ $24/ton ÷ 4 years)	12.00
Nitrogen (280 lbs. @ $.24)	67.20
Phosphate (24 lbs. @ $.30)	7.20
Potash (24 lbs. @ $.13)	3.12
Ryegrass seed (20 lbs. @ $.16)	3.20
Clover seed (5 lbs. @ $2.00)	10.00
Machinery (fuel, lube, repair)	2.78
Tractor (fuel, lube, repair)	5.43
Labor (tractor & machinery) (2.62 hrs. @ $4.00)	10.49
Interest on operating capital ($41.57@ 13%)	5.40
Total specified variable costs	126.82
Fixed costs	
Machinery	5.99
Tractors	3.39
Prorated established cost ($133.50 ÷ 10 years)	13.35
Total specified fixed costs	22.72
Total specified costs	149.55

Appendix Table 15.—Estimated Costs Per Acre for Bermuda + Ryegrass, Macon Ridge Branch Station, Winnsboro, 1976-80

Item	Cost per acre
Variable costs	
Lime (2 tons@ $24/ton ÷ 4 years)	12.00
Nitrogen (280 lbs. @ $.24)	67.20
Phosphate (24 lbs. @ $.30)	7.20
Potash (24 lbs. @ $.13)	3.12
Ryegrass seed (20 lbs. @ $.16)	3.20
Machinery (fuel, lube, repair)	2.78
Tractor (fuel, lube, repair)	5.43
Labor (tractor & machinery) (2.62 hrs. @ $4.00)	10.49
Interest on operating capital ($41.57@ 13%)	5.40
Total specified variable costs	116.82
Fixed costs	
Machinery	5.99
Tractors	3.39
Prorated established cost ($133.50 ÷ 10 years)	13.35
Total specified fixed costs	22.73
Total specified costs	139.55

Appendix Table 16.—Estimated Costs Per Acre of Prepared Seedbed for Wheat + Ryegrass, Macon Ridge Branch Station, Winnsboro, 1976-80

Item	Cost per acre
Variable costs	
Lime (1 ton @ $24/ton ÷ 4 years)	6.00
Nitrogen (140 lbs. @ $.24)	33.60
Phosphate (12 lbs. @ $.30)	3.60
Potash (12 lbs. @ $.13)	1.56
Wheat seed (1 bu. @ $12.00)	12.00
Ryegrass seed (20 lbs. @ $.16)	3.20
Machinery (fuel, lube, repair)	3.95
Tractor (fuel, lube, repair)	7.16
Labor (tractor & machinery) (2.85 hrs. @ $4.00)	11.42
Interest on operating capital ($34.66 @ 13%)	4.51
Total specified variable costs	86.99
Fixed costs	
Machinery	7.57
Tractors	4.54
Total specified fixed costs	12.10
Total specified costs	99.10

Appendix Table 17.—Estimated Costs Per Acre of Prepared Seedbed for Millet, Macon Ridge Branch Station, Winnsboro, 1976-80

Item	Cost per acre
Variable costs	
Lime (1 ton @ $24/ton ÷ 4 years)	6.00
Nitrogen (140 lbs. @ $.24)	33.60
Phosphate (12 lbs. @ $.30)	3.60
Potash (12 lbs. @ $.13)	1.56
Millet seed (30 lbs. @ $.18)	5.40
Machinery (fuel, lube, repair)	3.95
Tractor (fuel, lube, repair)	7.16
Labor (tractor & machinery) (2.85 hrs. @ $4.00)	11.42
Interest on operating capital ($20.37 @ 13%)	2.65
Total specified variable costs	75.34
Fixed costs	
Machinery	7.57
Tractors	4.54
Total specified fixed costs	12.10
Total specified costs	87.44

Appendix Table 18.—Estimated Hay Harvesting Costs for 1-Ton Yield Per Acre, Half Ton Per Cutting, Macon Ridge Branch Station, Winnsboro, 1976-80

Item	Cost per acre
Variable costs	
Harvest costs	
Twine	.38
Machinery (fuel, lube, repair)	5.67
Tractor (fuel, lube, repair)	12.13
Labor (tractor & machinery) (2.40 hrs. @ $4.00)	9.61
Total specified variable costs	27.79
Fixed costs	
Machinery	6.42
Tractors	7.69
Total specified fixed costs	14.10
Total specified costs	41.90

Appendix Table 19.—Estimated Hay Production Costs for 4-Ton Yield Per Acre, Macon Ridge Branch Station, Winnsboro, 1976-80

Item	Cost per acre
Variable costs	
Preharvest	
Lime (320 lbs. @ $24/ton)	3.84
Nitrogen (180 lbs. @ $24)	43.10
Phosphate (32 lbs. @ $30)	9.57
Potash (63 lbs. @ $.13)	8.13
Machinery (fuel, lube, repair)	1.99
Labor (tractor & machinery) (1.52 hrs. @ $4.00)	6.07
Interest on operating capital ($25.14 @ 13%)	3.27
Subtotal, preharvest	75.97
Harvest costs	
Twine (4 lbs. @ $.38)	1.52
Machine (fuel, lube, repair)	12.07
Tractor (fuel, lube, repair)	42.06
Labor (tractor & machinery) (7.42 hrs.@ $4.00)	29.66
Subtotal harvest	85.31
Total specified variable costs	161.28
Fixed costs	
Machinery	19.07
Tractors	26.85
Prorated established cost ($133.50 ÷ 10 years)	13.35
Land (net rent)	15.00
Total specified fixed costs	74.27
Total specified costs	235.55

Appendix Table 20.—Estimated Costs for Pasture System I, Macon Ridge Branch Station, Winnsboro, 1976-80

Item	Amount	
	24 cows	per cow
	Dollars	
Variable costs		
Bermuda + clover + ryegrass (24 acres @ $126.82)	3043.68	126.82
Hay produced (18 tons @ $27.79)	500.22	20.84
Hay purchased (13.50 tons @ $40.32)	544.32	22.68
Protein supplement (3.72 cwt. @ $11.00)	40.92	1.71
Medication (24 head @ $9.50)	228.00	9.50
Minerals (4.80 cwt. @ $9.00)	43.20	1.80
Tractor (fuel, lube, repair)	14.72	.61
Machinery (fuel, lube, repair)	27.55	1.15
Equipment (fuel, lube, repair)	114.18	4.76
Labor		
Tractor and machinery (57.72 hrs. @ $4.00)	230.86	9.62
Equipment (30 hrs. @ $4.00)	120.00	5.00
Livestock (145.25 hrs. @ $4.00)	581.00	24.21
Interest on operating capital ($1612.78 @ 13%)	209.66	8.69
Total specified variable costs	5698.31	237.39
Fixed costs		
Pastures (24 acres @ $22.73)	545.52	22.73
Hay produced (18 tons @ $14.10)	253.80	10.58
Hay purchased (13.50 tons @ $18.57)	250.70	10.45
Interest on livestock capital ($17,399.99 @ 13%)	2262.00	94.25
Interest on other equipment ($1794.00 @ 13%)	233.22	9.72
Depreciation on other equipment	258.40	10.77
Other fixed cost, machinery & equipment	141.15	5.88
Total specified fixed costs	3944.78	164.38
Total specified costs	9643.09	401.77
Pounds calf produced	8640	360
Total specified costs per hundredweight		111.60

Appendix Table 21.—Estimated Costs for Pasture System II, Macon Ridge Branch Station, Winnsboro, 1976-80

Item	Amount	
	24 cows	per cow
	Dollors	
Variable costs		
Bermuda + clover + ryegrass (22 acres @ $126.82)	2790.04	116.25
Calf Creep		
Wheat + ryegrass (2 acres @ $86.99)	173.98	7.25
Millet (2 acres @ $75.34)	150.68	6.28
Hay produced (13 tons @ $27.79)	361.27	15.05
Hay purchased (18.5 tons @ $40.32)	745.92	31.08
Protein supplement (3.72 cwt. @ $11.00)	40.92	1.71
Medication (24 head @ $9.50)	228.00	9.50
Minerals (4.80 cwt. @ $9.00)	43.20	1.80
Tractor (fuel, lube, repair)	14.72	.61
Machinery (fuel, lube, repair)	27.55	1.15
Equipment (fuel, lube, repair)	114.18	4.76
Labor		
Tractor and machinery (57.72 hrs. @ $4.00)	230.86	9.62
Equipment (30 hrs. @ $4.00)	120.00	5.00
Livestock (145.25 hrs. @ $4.00)	581.00	24.21
Interest on operating capital ($1742.38 @ 13%)	226.51	9.41
Total specified variable costs	5848.82	243.68
Fixed costs		
Pastures (24 acres @ $21.85)	524.40	21.85
Hay produced (18 tons @ $14.10)	253.80	10.58
Hay purchased (13.5 tons @ $18.57)	250.70	10.45
Interest on livestock capital ($17,399.99 @ 13%)	2262.00	94.25
Interest on other equipment ($1794.00 @ 13%)	233.22	9.72
Depreciation on other equipment	258.40	10.77
Other fixed cost, machinery & equipment	141.15	5.88
Total specified fixed costs	3923.66	163.50
Total specified costs	9772.48	407.18
Pounds calf produced	10,104	421
Total specified costs per hundredweight		96.72

Appendix Table 22.—Estimated Costs for Pasture System III, Macon Ridge Branch Station, Winnsboro, 1976-80

Item	Amount	
	24 cows	per cow
	-------------Dollars-------------	
Variable costs		
Bermuda + ryegrass (24 acres @ $116.82)	2803.68	116.82
Hay produced (19 tons @ $27.79)	528.01	22.00
Hay purchased (12.5 tons @ $40.32)	504.00	21.00
Protein supplement (3.72 cwt. @ $11.00)	40.92	1.71
Medication (24 head @ $9.50)	228.00	9.58
Minerals (4.8 cwt. @ $9.00)	43.20	1.80
Tractor (fuel, lube, repair)	14.72	.61
Machinery (fuel, lube, repair)	27.55	1.15
Equipment (fuel, lube, repair)	114.18	4.76
Labor		
Tractor and machinery (57.72 hrs. @ $4.00)	230.86	9.62
Equipment (30 hrs. @ $4.00)	120.00	5.00
Livestock (145.25 hrs. @ $4.00)	581.00	24.21
Interest on operating capital ($1528.60 @ 13%)	198.72	8.23
Total specified variable costs	5434.84	226.41
Fixed costs		
Pastures (24 acres @ $22.73)	545.52	22.73
Hay produced (19 tons @ $14.10)	267.90	11.15
Hay purchased (12.5 tons @ $18.57)	232.13	9.67
Interest on livestock capital ($17,399.99 @ 13%)	2262.00	94.25
Interest on other equipment ($1794.00 @ 13%)	233.22	9.72
Depreciation on other equipment	258.40	10.77
Other fixed cost, machinery & equipment	141.15	5.88
Total specified fixed costs	3940.31	164.17
Total specified costs	9375.15	390.58
Pounds calf produced	9120	380
Total specified costs per hundredweight		102.78

Appendix Table 23.—Estimated Costs for Pasture System IV, Macon Ridge Branch Station, Winnsboro, 1976-80

Item	Amount	
	24 cows	per cow
	--------------Dollars--------------	
Variable costs		
Bermuda + clover + ryegrass (24 acres @ $126.82)	3043.68	126.82
Hay produced (18 tons @ $27.79)	500.22	20.84
Hay purchased (13.5 tons @ $40.32)	544.32	22.68
Protein supplement (3.72 cwt. @ $11.00)	40.92	1.71
Medication (24 head @ $9.50)	228.00	9.50
Minerals (4.80 cwt. @ $9.00)	43.20	1.80
Tractor (fuel, lube, repair)	14.72	.61
Machinery (fuel, lube, repair)	27.55	1.15
Equipment (fuel, lube, repair)	114.18	4.76
Labor		
Tractor and machinery (57.72 hrs. @ $4.00)	230.86	9.62
Equipment (30 hrs. @ $4.00)	120.00	5.00
Livestock (145.25 hrs. @ $4.00)	581.00	24.21
Interest on operating capital ($1612.78 @ 13%)	209.66	8.69
Total specified variable costs	5698.31	237.39
Fixed costs		
Pastures (24 acres @ $22.73)	545.52	22.73
Hay produced (18 tons @ $14.10)	253.80	10.58
Hay purchased (13.5 tons @ $18.57)	250.70	10.45
Interest on livestock capital ($17,399.99 @ 13%)	2262.00	94.25
Interest on other equipment ($1794.00 @ 13%)	233.22	9.72
Depreciation on other equipment	258.40	10.77
Other fixed cost, machinery & equipment	141.15	5.88
Total specified fixed costs	3944.78	164.38
Total specified costs	9643.09	401.77
Pounds calf produced	7536	314
Total specified costs per hundredweight		127.95

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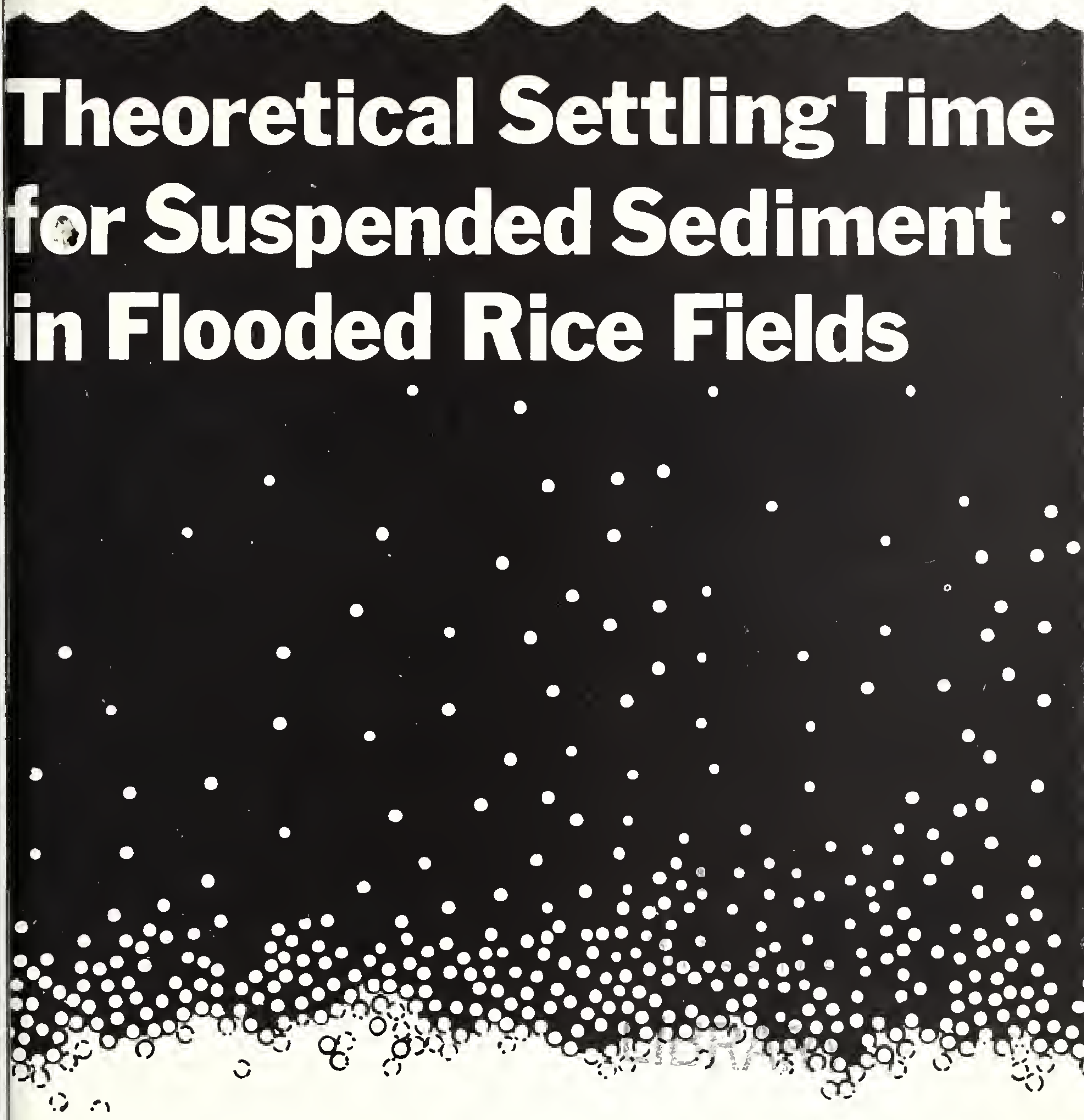
Theoretical Settling Time for Suspended Sediment in Flooded Rice Fields



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Theoretical Settling Time for Suspended Sediment in Flooded Rice Fields

R. J. EDLING,[1] B. J. MILLER,[2] AND F. OBETEN[1]

Water-leveling techniques are used in reshaping the land surface for rice growing in areas in Louisiana. Lawson (1962) has described the water-leveling technique in Louisiana in detail. The technique involves flooding the area to be leveled, then stirring the flooded surface with a tractor or tractor-drawn implement. Soil material put in suspension by the stirring may be removed from the area if the impounded water is immediately drained. Delaying drainage allows settling and reduces the amount of suspended sediment removed in the drained water. Complete removal of suspended material by sedimentation is not practical due to the long settling times required for the smaller particles. Very small sediment particles may remain in suspension indefinitely due to movement of water molecules.

To the author's knowledge, no on-site field experiments have been conducted to evaluate actual settling times for suspended sediment after water leveling in flooded rice fields. Time periods involved in settling of suspended sediments are strongly dependent on factors, in addition to soil textures and depth of water, that can vary independently among locations and from one time to another. The most important of these factors are (1) the degree of soil dispersion, which largely depends on the kind and amounts of salts in the soil and the extent to which the soil has been stirred, and (2) the development of currents in the water caused by changes in water temperature, wind action, or other disturbances. However, theoretical settling times based on reasonable assumptions can be calculated and used as a reference for deciding the length of time to allow settling to proceed after water leveling flooded fields.

This bulletin will provide estimates of the amount of sediment that will have settled at specific times after stirring so that an adequate delay time can be determined to prevent removal of large quantities of sediment when the area is drained. Use of the tables requires only that the depth of the impounded water and texture of the surface soil be known.

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Methods

Theoretical basis for the settling time calculations is given by Stokes' Law (Baver, 1965). Stokes' Law is also used in the laboratory determination of particle size distribution in soils. Certain assumptions are commonly made in either application. Those made in this study include the following: a constant temperature, assumed to be 86° F; rigid, smooth, spherical soil particles; constant soil particle density (2.65 grams per cubic centimeter); and that Stokes' Law is applicable to the particle size range represented in the soil.

Additional assumptions are necessary when application is made to settling of particles in water-leveled fields. It is assumed that the suspended soil particles are dispersed, that is they do not clump together, and that the particles are uniformly mixed throughout the water volume and are present in the same relative proportions as they occur in the soil surface horizon. It is also assumed that wind and diurnal temperature changes have no influence on settling and that water movement and agitation stop on completion of water leveling.

The form of Stokes' Law used in this study is:

$$U = \frac{2}{9} \frac{(dp - d)}{m} gr^2$$

where U = particle fall velocity, centimeters per second
g = acceleration of gravity, 980 centimeters per second squared
dp = particle density, 2.65 grams per cubic centimeter
d = density of water, .99707 gram per cubic centimeter
r = mean particle radius, centimeters, and
m = absolute viscosity of water, .008904 poise.

The 12 soil texture classes recognized by soil scientists are defined in terms of definite allowed ranges in the content of sand-, silt-, and clay-size particles. The soil texture classes and size range of the clay-, silt-, and various sand-size particles are given in Figure 1.

A representative percent by weight of sand-, silt-, and clay-size particles was assigned to each texture class to calculate theoretical settling time for the suspended sediment. These values are given in Table 1 and plotted in Figure 1. The clay texture class was divided into two subclasses—heavy clay, with an assumed average of 65 percent clay; and light clay, with an assumed average of 45 percent clay. Theoretical settling times were calculated for each texture class even though water-leveling techniques are not normally used on soils with certain textures, for example, sands.

A computer program was developed to perform the necessary calculations and prepare graphs of the results. For calculation purposes, the clay

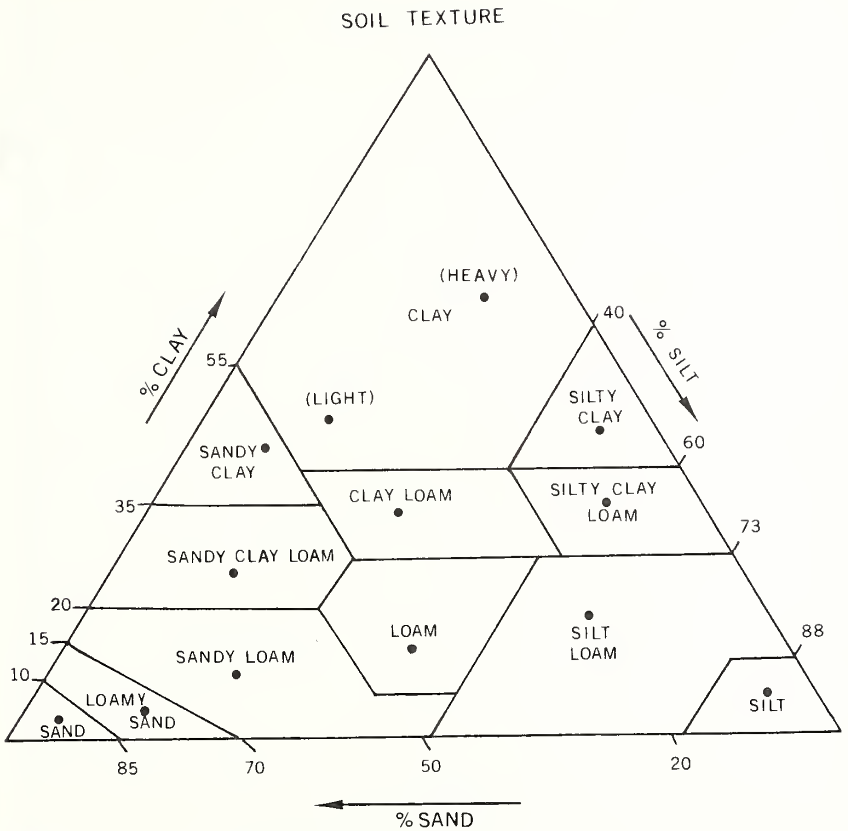

Figure 1.—The 12 soil texture classes and the size range of their particles.

Table 1.—Percent sand-, silt-, and clay-size particles assigned each soil texture class for calculating time and cumulative percent of soil particle sedimentation

Soil texture class	Clay	Silt	Sand
		%	
Heavy clay	65	25	10
Light clay	45	25	30
Silty clay	45	50	5
Sandy clay	45	10	45
Silty clay loam	35	55	10
Clay loam	35	30	35
Sandy clay loam	25	15	60
Silt loam	18	62	20
Loam	15	45	40
Sandy loam	15	25	60
Silt	8	87	5
Loamy sand	7	15	78
Sand	4	8	88

fraction was divided into four size groups, the silt particles into six size groups, and the sand into 13 size groups (Table 2). The percentage by weight of sand, silt, and clay in each texture class was subdivided equally among each of the groups in that particular size fraction. The median particle size of each group was used in the Stokes' Law equation to determine velocity of fall. Particle fall velocity and different water depths (6, 12, 18, and 24 inches) were then used to calculate the percent of that group that settles in a given time from the different water depths. Settling times in 3-hour increments in 336 hours (14 days) were used. The product of the percentage of a given group of particles that falls at a given time and the percentage of the total weight that group represents gives the weight of sediment in that group that has settled during that time period. The sum of all settled group weights in a given time period is the total weight settled for that texture class.

Table 2.—Subdivisions of clay-, silt-, and sand-size fractions used in calculations of time and cumulative sediment percentages

Particle size fraction	Size range mm
Clay	0.0000-0.0005
	0.0005-0.0010
	0.0010-0.0015
	0.0015-0.0020
Silt	0.0020-0.0100
	0.0100-0.0180
	0.0180-0.0260
	0.0260-0.0340
	0.0340-0.0420
	0.0420-0.0500
Sand	0.0500-0.2125
	0.2125-0.3750
	0.3750-0.5375
	0.5375-0.7000
	0.7000-0.8625
	0.8625-1.0250
	1.0250-1.1875
	1.1875-1.3500
	1.3500-1.5125
	1.5125-1.6750
	1.6750-1.8375
	1.8375-2.0000

Results

The results are presented as cumulative percent by weight of soil particles that settled versus settling time for a given soil texture class (Tables 3 to 5). The soil texture class represented is identified in the table. The values are the percent of the soil particles initially in suspension that have settled after given periods of time where depths are 6, 12, 18, and 24 inches. For example, 89.5 percent of the particles in the silt loam texture class (Table 3) will have settled in 24 hours where the water depth is 12 inches. Thus, the tables can be used to obtain a theoretical estimate of the percent by weight of particles in suspension that will have settled after a given time provided the soil texture class and depth of water are known.

Estimates other than those for 6-, 12-, 18-, and 24-inch water depths may be obtained by interpolation. Estimates can be useful in determining the settling times required to minimize soil losses resulting from drainage of water-leveled areas. Sources of information concerning the surface horizon texture of specific soil areas include Soil Survey reports, USDA-Soil Conservation Service, Louisiana Cooperative Extension Service, and private agricultural consultants.

The major areas of rice production in Louisiana are on soils having either silt loam, silty clay loam, silty clay, or clay surface horizon textures. Crowley, Mowata, Kinder, Acadia, Caddo, and Calhoun are examples of soils that, in most areas, have silt loam textures. Clay or silty clay surface horizon textures are common in the Sharkey, Alligator, Moreland, Perry, Portland, and Judice soils. Silty clay loam textures occur in some areas of soils such as the Morey and Mowata. In places, small areas of soils with loam or very fine sandy loam surface horizon textures are used for rice production. Soil with clay loam, sandy clay, sandy clay loam, loamy sand, or sand textures are rarely, if ever, used for growing rice in Louisiana.

The cumulative percentages in Tables 3 to 5 are theoretical values based on Stokes' Law and the assumptions already indicated. In using the estimates in these tables, it may be necessary to consider the effects of some of the main factors that affect the actual settling of soil particles in water-leveled fields.

It is assumed that water motion stops when water-leveling activity ceases. Strong winds or other factors that agitate the water can result in longer periods being required for sedimentation than indicated by the tables. Soil particles in suspension initially are assumed to be representative of the surface soil horizon. The actual amount of soil in suspension initially can have a wide range but is only a small fraction of the total soil surface horizon.

The cumulative percentages given in Table 3 to 5 do not assume a certain amount of soil initially in suspension. The values in Tables 3 to 5 reflect the theoretical percent settled of whatever quantity of soil in that

Table 3.—Theoretical percentage of suspended sediment that has settled after the given times by water depth for specific textures (see Table 1 or Figure 1)

Time (days)	Soil texture															
	Sandy clay				Loam				Clay loam				Silt loam			
	Water depth (inches)															
	6	12	18	24	6	12	18	24	6	12	18	24	6	12	18	24
	% sediment settled															
.25	64.2	59.5	58.0	57.2	88.0	86.4	85.9	85.6	72.2	68.5	67.3	66.7	85.7	83.8	83.2	82.9
.50	73.6	64.2	61.1	59.5	91.1	88.0	86.9	86.4	79.5	72.2	69.7	68.5	89.5	85.7	84.4	83.8
.75	77.8	68.9	64.2	61.9	92.5	89.5	88.0	87.2	82.8	75.8	72.2	70.4	91.1	87.6	85.7	84.8
1.0	81.7	73.6	67.4	64.2	93.8	91.1	89.0	88.0	85.8	79.5	74.6	72.2	92.7	89.5	86.9	85.7
1.5	84.0	77.8	73.6	68.9	94.6	92.5	91.1	89.5	87.6	82.8	79.5	75.8	93.6	91.1	89.5	87.6
2	86.3	81.7	76.5	73.6	95.3	93.8	92.1	91.1	89.3	85.8	81.7	79.5	94.5	92.7	90.6	89.5
3	89.9	84.0	81.7	77.8	96.5	94.6	93.8	92.5	92.2	87.6	85.8	82.8	96.0	93.6	92.7	91.1
4	90.4	86.3	83.3	81.7	96.7	95.3	94.3	93.8	92.5	89.3	87.0	85.8	96.1	94.5	93.3	92.7
5	90.8	88.5	84.8	82.9	96.8	96.1	94.8	94.2	92.9	91.1	88.2	86.7	96.3	95.4	93.9	93.2
6	91.3	89.9	86.3	84.0	97.0	96.5	95.3	94.6	93.2	92.2	89.3	87.6	96.5	96.0	94.5	93.6
7	91.7	90.1	87.8	85.2	97.0	96.6	95.8	95.0	93.6	92.3	90.5	88.5	96.7	96.1	95.1	94.1
8	92.2	90.4	89.3	86.3	97.3	96.7	96.3	95.3	93.9	92.5	91.7	89.3	96.9	96.1	95.7	94.5
9	92.6	90.6	89.9	87.4	97.4	96.8	96.5	95.7	94.2	92.7	92.2	90.2	97.0	96.2	96.0	95.0
10	93.0	90.8	90.1	88.5	97.6	96.8	96.6	96.1	94.6	92.9	92.3	91.1	97.2	96.3	96.0	95.4
11	93.5	91.0	90.2	89.6	97.7	96.9	96.6	96.5	94.9	93.0	92.4	91.9	97.4	96.4	96.1	95.9
12	93.9	91.3	90.4	89.9	97.9	97.0	96.7	96.5	95.3	93.2	92.5	92.2	97.6	96.5	96.1	96.0
13	94.4	91.5	90.5	90.0	98.0	97.1	96.7	96.6	95.6	93.4	92.6	92.2	97.8	96.6	96.2	96.0
14	94.8	91.7	90.7	90.1	98.2	97.1	96.8	96.6	96.0	93.6	92.7	92.3	97.9	96.7	96.3	96.1

Table 4.—Theoretical percentage of suspended sediment that has settled after the given times by water depth for specific textures (see Table 1 or Figure 1)

Time (days)	Soil texture															
	Sand				Loamy sand				Sandy loam				Sandy clay loam			
	Water depth (inches)															
	6	12	18	24	6	12	18	24	6	12	18	24	6	12	18	24
	%sediment settled															
.25	96.5	96.1	95.9	95.9	94.2	93.4	93.2	93.1	87.9	86.3	85.8	85.5	80.0	77.4	76.5	76.1
.50	97.3	96.5	96.2	96.1	95.6	94.2	93.7	93.4	91.0	87.9	86.9	86.3	85.2	80.0	78.2	77.4
.75	97.7	96.9	96.5	96.3	96.3	94.9	94.2	93.8	92.4	89.5	87.9	87.1	87.5	82.6	80.0	78.7
1.0	98.0	97.3	96.8	96.5	96.9	95.6	94.6	94.2	93.7	91.0	88.9	87.9	89.7	85.2	81.7	80.0
1.5	98.2	97.7	97.3	96.9	97.2	96.3	95.6	94.9	94.5	92.4	91.0	89.5	91.0	87.5	85.2	82.6
2	98.4	98.0	97.6	97.3	97.6	96.9	96.1	95.6	95.2	93.7	92.0	91.0	92.2	89.7	86.8	85.2
3	98.8	98.2	98.0	97.7	98.1	97.2	96.9	96.3	96.5	94.5	93.7	92.4	94.3	91.0	89.7	87.5
4	98.8	98.4	98.2	98.0	98.2	97.6	97.1	96.9	96.6	95.2	94.3	93.7	94.5	92.2	90.6	89.7
5	98.8	98.6	98.3	98.1	98.3	97.9	97.4	97.1	96.8	96.0	94.8	94.1	94.8	93.5	91.4	90.4
6	98.9	98.8	98.4	98.2	98.4	98.1	97.6	97.2	96.9	96.5	95.2	94.5	95.0	94.3	92.2	91.0
7	98.9	98.8	98.6	98.3	98.4	98.2	97.8	97.4	97.1	96.5	95.7	94.9	95.3	94.4	93.1	91.6
8	99.0	98.8	98.7	98.4	98.5	98.2	98.0	97.6	97.2	96.6	96.2	95.2	95.5	94.5	93.9	92.2
9	99.0	98.8	98.8	98.5	98.6	98.3	98.1	97.8	97.4	96.7	96.5	95.6	95.8	94.6	94.3	92.9
10	99.0	98.8	98.8	98.6	98.6	98.3	98.2	97.9	97.5	96.8	96.5	96.0	96.0	94.8	94.3	93.5
11	99.1	98.9	98.8	98.7	98.7	98.3	98.2	98.1	97.7	96.8	96.6	96.4	96.2	94.9	94.4	94.1
12	99.1	98.9	98.8	98.8	98.8	98.4	98.2	98.1	97.8	96.9	96.6	96.5	96.5	95.0	94.5	94.3
13	99.2	98.9	98.8	98.8	98.8	98.4	98.2	98.2	98.0	97.0	96.7	96.5	96.7	95.1	94.6	94.3
14	99.2	98.9	98.9	98.8	98.9	98.4	98.3	98.2	98.1	97.1	96.7	96.5	97.0	95.3	94.7	94.4

Table 5.—Theoretical percentage of suspended sediment that has settled after the given times by water depth for specific textures (see Table 1 or Figure 1)

	Soil texture																			
	Silty clay loam				Silt				Silty clay				Clay (light)				Clay (heavy)			
Time	Water depth (inches)																			
(days)	6	12	18	24	6	12	18	24	6	12	18	24	6	12	18	24	6	12	18	24
	% sediment settled																			
.25	72.3	68.8	67.4	66.8	93.7	92.8	92.6	92.4	64.4	59.7	58.1	57.3	64.3	59.6	58.0	57.2	48.5	41.8	39.5	38.4
.50	79.6	72.3	69.8	68.6	95.3	93.7	93.1	92.8	73.8	64.4	61.3	59.7	73.7	64.3	61.2	59.6	62.1	48.5	44.0	41.8
.75	82.9	75.9	72.3	70.5	96.1	94.5	93.7	93.3	78.0	69.1	64.4	62.0	77.9	69.0	64.3	61.9	68.2	55.3	48.5	45.1
1.0	85.9	79.6	74.7	72.3	96.8	95.3	94.2	93.7	81.9	73.8	67.5	64.4	81.8	73.7	67.4	64.3	73.8	62.1	53.1	48.5
1.5	87.7	82.9	79.6	75.9	97.2	96.1	95.3	94.5	84.2	78.0	73.8	69.1	84.1	77.9	73.7	69.0	77.2	68.2	62.1	55.3
2	89.4	85.9	81.8	79.6	97.6	96.8	95.9	95.3	86.4	81.9	76.7	73.8	86.3	81.8	76.6	73.7	80.4	73.8	66.3	62.1
3	92.3	87.7	85.9	82.9	98.2	97.2	96.8	96.1	90.1	84.2	81.9	78.0	90.0	84.1	81.8	77.9	85.7	77.2	73.8	68.2
4	92.6	89.4	87.1	85.9	98.3	97.6	97.1	96.8	90.5	86.4	83.5	81.9	90.4	86.3	83.4	81.8	86.3	80.4	76.1	73.8
5	93.0	91.2	88.3	86.8	98.4	98.0	97.3	97.0	91.0	88.7	85.0	83.1	90.9	88.6	84.8	83.0	86.9	83.6	78.2	75.5
6	93.3	92.3	89.4	87.7	98.5	98.2	97.6	97.2	91.4	90.1	86.4	84.2	91.3	90.0	86.3	84.1	87.6	85.7	80.4	77.2
7	93.7	92.4	90.6	88.6	98.6	98.3	97.9	97.4	91.9	90.3	87.9	85.3	91.8	90.2	87.8	85.2	88.2	86.0	82.6	78.8
8	94.0	92.6	91.8	89.4	98.6	98.3	98.1	97.6	92.3	90.5	89.4	86.4	92.2	90.4	89.6	86.3	88.9	86.3	84.7	80.4
9	94.4	92.8	92.3	90.3	98.7	98.4	98.2	97.8	92.8	90.8	90.1	87.6	92.7	90.6	90.0	87.5	89.5	86.6	85.7	82.0
10	94.7	93.0	92.4	91.2	98.8	98.4	98.3	98.0	93.2	91.0	90.2	88.7	93.1	90.9	90.1	88.6	90.2	86.9	85.9	83.6
11	95.1	93.1	92.5	92.0	98.9	98.4	98.3	98.2	93.7	91.2	90.4	89.8	93.6	91.1	90.3	89.7	90.8	87.3	86.1	85.2
12	95.4	93.3	92.6	92.3	99.0	98.5	98.3	98.2	94.1	91.4	90.5	90.1	94.0	91.3	90.4	90.0	91.5	87.6	86.3	85.7
13	95.7	93.5	92.7	92.4	99.0	98.5	98.3	98.3	94.6	91.6	90.7	90.2	94.5	91.5	90.6	90.1	92.1	87.9	86.5	85.8
14	96.1	93.7	92.8	92.4	99.1	98.6	98.4	98.3	95.0	91.9	90.8	90.3	94.9	91.8	90.7	90.2	92.8	88.2	86.7	86.0

texture class was initially in suspension.

The percent by weight of particles in suspension is not indicative of relative degree of turbidity or vice versa. For example, a small percentage of clay-size particles in suspension can result in high turbidity. Particle size distributions within a soil texture class that differ from those used in the calculations can result in expected sedimentation times that differ slightly from the calculated. In comparison with the assigned particle size distributions (Table 1, Figure 1), a larger percentage of sand and/or silt and smaller percentages of clay result in sedimentation times slightly less than the calculated periods. Conversely, a greater percentage of clay will result in slightly greater sedimentation times. Finally, few if any soil surface horizons are completely dispersed. This undispersed condition results in clumping together (flocculation) of smaller particles so that they settle at a faster rate than if they are dispersed. This can result in shorter time periods for a given percent to settle than in shown.

In conclusion, the theoretical settling times in Table 3 to 5 can serve as a guide for decision-making regarding the length of time to allow for settling in order to prevent removal of large quantities of sediment when draining fields after they have been water-leveled. Changes in temperature and winds, or other disturbances that result in currents in the water, will result in a lower percent settling out at a given time than is indicated in Tables 3 to 5. Conversely, the flocculation characteristic of essentially all soils will result in a larger percent settling out at a given time than is indicated in the tables.

The methods applied in obtaining estimates of settling time have other applications. For example, settling ponds used to allow deposition of sediment are used in strip mine reclamation to remove potential pollutants from runoff water. The estimation of deposition in coastal wetlands could also be approached by methods used in this paper.

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Nutrition of Navel Oranges In Southern Louisiana

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AND S. D. THIBODEAUX[3]

Washington navel oranges are widely grown in several of the southernmost states of the country where minimum temperatures in winter are not low enough to kill or seriously damage the trees. Principal production areas for this fruit are in California, Arizona, Texas, and Florida. A relatively small amount of it also is produced in southern Louisiana.

Extensive research and practical experience in the main production areas have shown that light and medium-textured soils were preferable for navel oranges (*20*),[4] although it was recognized that many of these soils were relatively infertile. The consensus among the researchers was that the better drainage and aeration provided by the lighter soils were of primary importance to the crop, and the necessary plant nutrients that these soils could not supply in ample quantities could be provided as fertilizer applications, as indicated by experimental results in nutrition on these soils (*16, 20, 27, 28*). Also, the reaction of the lighter soils was generally found to be slightly to moderately acid, a condition considered favorable for growth and production of citrus crops (*20*).

Washington navel oranges are grown in Louisiana on soils considerably heavier (finer textured) than those mentioned in other citrus-growing areas. The navel orange production area in Louisiana is located on the Mississippi River Alluvial soils south of New Orleans in Plaquemines Parish. It has been shown both experimentally and in practice that navel oranges will grow well in this area and produce high yields of high-quality fruit. The peninsula of alluvial soil that extends southeastward from New Orleans into the Gulf of Mexico also provides a growing area that is less likely than

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[4] Italic numbers in parentheses refer to Literature Cited, page 62.

To simplify terminology, trade names are sometimes used. No endorsement of any product mentioned is intended, nor is criticism of unnamed products implied.

other parts of the state to experience winter temperatures low enough to kill navel orange trees. The soils in this area are of relatively recent deposition, having been laid down during the past few centuries by annual overflow and sedimentation of the Mississippi River before levees were built to confine the river to its main channel. These soils, derived from a conglomerate of materials eroded by winter rains and melting snow in the spring from soils in many more northern states in the Mississippi Valley and its distributaries, are quite variable in texture and composition. In general, however, they are lighter in texture near the river and become heavier and more poorly drained as one proceeds toward the back swamps that exist both east and west away from the river. The areas between these two extremes usually consist of medium-textured soils. The lighter soils in this group (sandy loam, fine sandy loam) are known by such series names as Convent, Crevasse, Robinsonville, etc., while the medium-textured ones (silt loam, silty clay loam) are usually classified as Commerce, Mhoon, etc. The heavier textured soils found nearer the back-swamps, such as Sharkey, Tunica, or Alligator, are usually avoided by navel orange growers. Most of the soils mentioned above have a slightly acid to neutral reaction in their natural state; however, extensive use of sulphur as an insecticide in this area and the acid rain resulting from industrial emissions, etc., in the proximity have rendered some of these soils (especially those not highly buffered) moderately acid (*8*). The organic matter content of these soils varies from about 1 percent in the lighter types to 4 percent or more in some of the heavier ones that have not been cultivated extensively (*8*). These soils are among the most fertile in the state (*8*) in terms of readily extractable phosphorus, potassium, calcium, and magnesium (*7*). It is a common practice by Louisiana navel orange growers to plow these soils into rows as high as possible (24 to 30 inches) to provide adequate drainage and maximum foraging area for tree roots (the water table is high here as many of these soils are near sea level and annual rainfall averages about 60 inches). Rows are usually 20 to 30 feet wide, with plants spaced from 15 to 30 feet apart on the row.

Review of Literature

The literature dealing with the nutrition of citrus crops is voluminous, and no attempt will be made to consider all of it here, especially in view of the vast differences in growing conditions, including soil differences, between the relatively small citrus area in Louisiana and other larger production areas of the country where most of the research on navel orange production has been conducted.

Reitz et al. (*28*), in an advisory bulletin to Florida citrus growers, pointed out that several factors may influence a fertilization program: soils, rootstocks, scions, age of tree, previous program of fertilization, insect and disease control, irrigation, and others. The "age of tree" component includes a consideration of young, nonbearing trees that are making relatively rapid growth as compared with older, heavily bearing trees from which a considerable amount of plant nutrients are removed annually in the harvested fruit. In this regard, Barnette (*4*) reported that an acre of 20-year-old grapefruit trees required 145 pounds of N, 27 pounds of P_2O_5, 277 pounds of K_2O, and 348 pounds of CaO for good growth and production. Pyer (*26*) found that orange fruits contained an average of .149 percent N,.055 percent P_2O_5, and .249 percent K_2O. According to Oppenheim (*23*), the following amounts of nutrients were removed in a 3-year cropping cycle by 400 citrus trees, including that in the wood removed in prunings: oranges in heavy production—242 kilograms per hectare of N, 54 kilograms per hectare of P_2O_5, 205 kilograms per hectare of K_2O, and 315 kilograms per hectare of CaO. Another worker, Bryan (*9*), in an analysis of orange fruit, reported the following contents of 100 cases of fruit: 10 pounds of N, 3.5 pounds of P_2O_5, 15 pounds of K_2O, and 2.5 pounds of MgO. From these findings it is apparent that plant nutrients in significant amounts are removed annually in the fruit; this becomes an important factor, along with the nutrient requirements of other parts of the plant, in planning a fertilization program.

Most authorities on citrus tree nutrition agree that nitrogen is the element most often lacking in the soil, and that its application usually produces the greatest response. Growers on the lighter soils usually make two applications per year, one in late winter and another in mid-summer. Jacob and Uexkull (*20*) point out that the optimum rate varies greatly with the age and productivity of the tree, ranging from 0.1 to 2 kilograms of N per tree. They (*20*) emphasize that a large tree in heavy production will lose about half of this maximum rate annually (about 1 kilogram per tree) in the harvested fruit. This would leave about half of the applied nitrogen to be utilized in other parts of the tree, not taking into account that additional N that may be supplied by the soil through decomposition of organic matter or the portion that may be lost by leaching or in other ways. On the lighter soils which are usually low in organic matter, the authorities in many cases are recommending use of 0.1 kilogram of N per tree per year of age (*20, 27, 28*). In other instances, the nitrogen recommendation becomes progressively larger as the trees attain a size and age for a significant amount of fruit production (*28*). Some authorities prefer to make N recommendations on an acre basis, usually within the range of 100 to 150 pounds per acre per year (*16*). More recently, with the adoption of leaf analysis by the workers in citrus nutrition, it has become feasible to relate the concentration of N in the foliage to good growth of the trees and to the desired yield levels without impairing the quality of the fruit. A deficiency of nitrogen in oranges is described by Jacob and Uexkull (*20*) "as the uniform loss of chlorophyll and yellowing of the leaves which, under prolonged N deficiency, readily fall off and the new fruits that are produced are small and have a thin leathery skin. In contrast, with excessive nitrogen dark green, abnormally large, coarse leaves are produced (*19*). Fruits of these trees are large, with a thick skin, late in ripening, and poor in quality.'' In this regard, Wallace et al. (*35*) found that excessive nitrogen caused increased citric acid and soluble solids in the fruit, while the percentage of juice in the fruit was reduced. A significant observation by Jacob and Uexkull (*20*) is that ''heavily cropping trees can tolerate large quantities of nitrogen without suffering any injurious effects, provided that at the same time they are well supplied with phosphate and potash.''

In orange trees growing in Florida soils, the level of nitrogen found in the foliage by Reitz et al. (*28*) that was closely associated with maximum production was within the range of 2.3 to 2.9 percent. These leaves were from bearing trees and were made up of 100 spring-flush leaves from 20 trees. The leaves were taken at 4 to 5 months of age (July-August) from nonfruiting twigs.

Similar levels of foliar N in bearing citrus trees are advocated by the California citrus nutrition research group, as explained by Embleton et al. (*16*. Nitrogen concentrates of 2.2 percent are considered deficient, while anything above 2.8 percent is believed to be excessive. This group selected the range of 2.4 to 2.6 percent N as optimum for bearing trees. They also emphasize the influence of size of crop removed annually upon the overall nitrogen requirements of the trees and indicate this factor may exert more influence on a fertilizer recommendation for a particular orchard than the soil type upon which it is grown.

The actual phosphorus requirement of citrus trees, as indicated by analysis of the foliage and fruit, appears to be much lower than the nitrogen requirement. Jacob and Uexkull (*20*) said ''about 0.08 percent P in the dry matter of the leaves seems to be the lower limit for an adequate supply.'' The Florida group led by Reitz (*28*) give a P range of 0.09 to 0.15 percent as satisfactory in the foliage. Reitz et al. (*28*) also give some soil test values for extractable P that they consider ample in supplying the phosphorus requirement of citrus trees growing on acid, sandy soil: acid ammonium acetate extractant (pH 4.8)—22 pounds of P per acre, Bray P_1 extractant—80 pounds of P per acre, or Bray P_2 extractant—130 pounds of P per acre. Embleton et al. (*16*), in studies with citrus leaf analysis in California, agreed with the Florida group that 0.09 percent P was the lower limit that should be allowed; however, they extended the upper limit of concentration and considered 0.29 percent as still not excessive.

According to Jacob and Uexkull (*20*) ''phosphorus deficiency is indicated by small, blue-green, lusterless leaves, which, under acute conditions of deficiency, show blue-green to bronze-brown discolorations and necrotic spots. The formation of new shoots is restricted; the leaves are easily shed, and a proportion of the twigs may die back.'' Also, as found by Aldrich (*1*), Lilleland (*21*), and Young and Forsee (*37*), the few fruits borne by such trees are of poor quality. They are small and characterized by a thick skin and a high acid content. Bouma (*5*) established a significant correlation between the phosphorus content of orange leaves and the quality of the fruit. De Vasconcellos (*15*) reported similar results.

Excessive phosphorus levels in the foliage of citrus is evidently a rare occurrence. On those occasions when the concentration exceeds 0.3 percent, a portion of the total P held in the leaves is undoubtedly precipitated as phosphate crystals of aluminum, iron, and/or maganese (*20*). It has been shown by West (*36*) and also by Chapman et al. (*10*) that inordinately high levels of soluble phosphate in the soil can reduce the absorption of zinc by citrus trees, resulting in zinc deficiency (Frenching).

Although the actual amount of phosphorus required by citrus trees is small as compared with the nitrogen requirement, it is still sometimes necessary to apply fairly large amounts of it to trees growing on many soils to fully satisfy the phosphorus needs. Jacob and Uexkull (*20*) suggest that at least 600 to 800 grams of phosphate per tree be applied to trees producing as much as five to six boxes of fruit per tree. The recommendation made by the California group (*16*) to their growers is qualified by the results of the foliar analysis from each grove; however, in the foliage found low in phosphorus an application of 2 to 3 pounds of P per tree is suggested each year until subsequent foliar analyses indicate the trees are taking up a sufficient amount of phosphate from the soil. In a different concept, the Florida group led by Reitz (*28*) said "the need for phosphorus can best be determined by soil test for the amount of available phosphorus already present in the soil. Leaf analysis also has some value, especially in case of pronounced deficiency. In most groves, phosphorus usage should be based on soils test." In the absence of soil test data, the Florida group (*28*) makes the following general recommendation: "Phosphorus from fertilizer applications accumulates in most peninsular Florida soils in available form. After many years of fertilizer use, most older groves contain adequate amounts of available phosphorus in the soil. Thus, mature citrus trees (over 20 years of age) growing on soil which has been fertilized with phosphorus for several years do not need further phosphorus additions to the soil. Younger groves that are just coming into full bearing (8 to 20 years of age) on new land should occasionally receive some phosphorus to replace that removed by the crop. The average crop fruit removes only about 20 pounds of P_2O_5 per acre. This need may be met by using 0.2 pound of P_2O_5 per box of fruit every fourth year. For example, using 400 pounds of ordinary 20 percent superphosphate per acre or one application of 800 pounds of 10-10-10 mixture every 4 years and no phosphate at other times will satisfy the need."

The amount of potassium normally required by citrus trees is evidently fairly large, as measured by the concentration of the element in the foliage and in the fruit. Chapman (*12*) found that leaf analysis provided a relatively reliable method of diagnosing potassium deficiency, which was associated with increased accumulation of calcium and magnesium in the foliage. His studies indicated a potassium level of 1.3 to 1.5 percent in leaves 3 to 7 months old was adequate. When the potassium content fell much below these levels, deficiency symptoms appeared on the foliage in the form of a thickening and puckering of the leaves, the disappearance of chlorophyll in the intercostal areas, and the subsequent incidence of necrotic spots. In addition, under extreme deficiency the degree of leaf-fall was increased, the shoot tips began to die back, and gummosis was present throughout the tree. Since the work of Chapman (*11*), other workers (*2, 9, 20, 21, 34*) have also shown that potassium deficiency in citrus trees can have a marked effect on fruit size as well as on the extent of premature fruit drop. Parker and Jones (*24*) were among the first to demonstrate conclusively that the potassium concentration of the leaves was the primary factor associated with differences in the size of fruit. This association has been confirmed by Arnot (*2*), Chapman (*11*), Haas (*17*), Harding (*18*), Innes (*19*), and Takahashi (*34*). Jacob and Uexkull (*20*) said that "apart from size, the quality of citrus fruits is relatively little influenced by potash deficiency. Under conditions of potash deficiency the fruits are small with a thin skin but with a good texture. Potash excess produces large coarse fruit of low quality. Large fruits of good quality result from a medium level of potash." There have been other contradictory reports in the literature (*29, 31, 32, 33*) about the possible effects of potassium on citrus fruit quality, particularly dealing with soluble solids, citric acid, and ascorbic acid. In addition, Samson (*30*) observed that a normal potassium content considerably improved the keeping quality of the fruit.

According to Reitz et al. (*28*), the preferred range of potassium in citrus leaves is 1.2 to 1.7 percent of the dry matter. Their potash fertilizer recommendation is tempered by the size and age of the trees, the variety, and the amount of fruit produced. The suggested rate: "On early and mid-season orange trees, apply 0.4 pound, and on late-season oranges and grapefruit apply 0.3 pound of K_2O per year per box of fruit, up to a maximum of about 250 pounds per acre." The California group (*16*) advocates an optimum of 0.7 to 1.09 percent concentration of potassium in citrus leaves. They consider leaves with no more than 0.4 percent as K-deficient and any level above 2 percent as excessive. Their potash fertilizer recommendations are based primarily on the potassium content of the leaves (*16*), in that only when the concentration falls below 0.7 percent is any potash recommended. They advise growers that: "'where effective, 2 to 5 pounds of K (equivalent to about 2.5 to 6 pounds of K_2O) per mature tree applied in a band around the dripline for 2 consecutive years have been successful. Effective applications normally last several years. Leaf analyses indicate when to reapply K. Tree damage has resulted from KCl applications, so K_2SO_4 is preferred." This point of some importance is one that has been stressed previously by Jacob and Uexkull (*20*): "Of the potash fertilizers, sulphate of potash is more suitable than the chloride because most varieties of citrus are sensitive to too high a concentration of chloride. Sulphate of potash-magnesia is particularly suitable as it contains 10 percent Mg in addition to 30 percent K_2O. As a fertilizer for the middleaged tree yielding a crop of 5 to 6 boxes of fruit, a reasonable dressing would be about 750 to 900 grams of K_2O."

In regard to soil reaction, Jacob and Uexkull (*20*) wrote that "although citrus plantations are still found with pH values of 4 to 7.8, the best growing conditions exist in the slightly acid range." According to Darcel (*13*), Peech (*25*), and Reitz et al. (*28*), the optimum pH for citrus lies between 5.5 and 6, because in this range "the phosphate and most of the trace elements are readily available." Even within this range, considerable quantities of calcium are absorbed from the soil by citrus trees. In fact, Barnette (*4*) has shown that 20-year-old trees require as much as 348 pounds of CaO per acre per year. This is related to the relatively high calcium requirement of citrus, as illustrated by results of foliar analyses. For example, Chapman et al. (*12*) found that many high-producing citrus orchards in California had leaves with 3 to 5.52 percent calcium. Only in leaves with calcium levels as low as 1.5 percent were deficiency symptoms present, and leaves with more than 7 percent were showing abnormalities indicative of nutrient imbalance.

The Florida group led by Reitz (*28*) suggests a soil pH range of 6 to 7 for citrus trees. They advise that "in young orchards a pH value of 6 to 6.5 should be satisfactory; however, in older orchards, and especially if the soil is known to contain high amounts of copper (which has been used for long periods as a fungicide), the soil pH should be maintained between 6.5 and 7. The use of either calcitic or dolomitic limestone is recommended, with the recognition that dolomite will often supply all of needed magnesium in groves where the pH has been raised through substantial applications of dolomite." This group of workers (*28*) considers a range of 2.5 to 5 percent of calcium in the dry matter of citrus leaves to be satisfactory. Reitz et al. (*28*) further state that "experimental data are not yet adequate to indicate the optimal calcium level in soils of different exchange capacity. Using a neutral extractant such as ammonium acetate buffered at pH 7, a soil calcium level of about 700 pounds (1,000 pounds of CaO) per acre on soils similar to Lakeland fine sand seems desirable. Soils with a higher exchange capacity would have a higher minimum requirement for extractable calcium."

Magnesium deficiency in citrus trees is shown first by the fully mature (lower) leaves, as pointed out by Jacob and Uexkull (*20*). "It occurs on particularly heavy-yielding trees or branches and is found in late summer or fall more often than in spring. The deficiency is characterized by the occurrence of chlorotic spots in the intercostal areas alongside the midrib. These spots increase in size with time while the leaf veins, especially the midrib, retain the chlorophyll longer, thus providing a means of differentiating between magnesium deficiency and nitrogen deficiency."

Evidently, the magnesium requirement of citrus trees is much smaller than the calcium requirement. The usual concentration of magnesium found in healthy, productive trees ranges from 0.2 to 0.4 percent in the foliage, according to Chapman et al. (*12*, *13*). A level of 0.15 percent is considered a deficiency, and 0.6 percent is thought to be excessive by this group. In later work in California, Embleton et al. (*16*) found magnesium concentrations of 0.26 to 0.6 percent to be optimum for citrus leaves, and the level was not considered excessive until it reached a point above 1 percent. This is a much wider range in concentration that that advocated by the Florida group (*28*), who suggest that magnesium should be present at 0.3 to 0.5 percent of the dry matter in the leaves. This group describes several alternative methods for meeting the magnesium needs of citrus trees growing on the acid, sandy soils of Florida, among which are: the choice of dolomite to adjust the soil pH to the proper range; the inclusion of either MgO or $MgSO_4$ in the regular annual fertilizer application, and/or the use of foliar sprays of $Mg(NO_3)_2$ as dilute solutions.

In addition to the plant nutrients discussed above, the need for relatively small (trace) amounts of several other elements has been established for citrus trees. These elements are manganese, zinc, iron, copper, boron, molybdenum, and probably chlorine. The requirement of citrus trees as indicated by the concentration of the element in the leaves has been given as 20 to 80 ppm for manganese by Chapman et al. (*12*). Under Florida conditions, however, 20 to 50 ppm of Mn appears to be the desired range (*28*). The citrus workers in California (*16*) suggest a wider range of 25 to 200 ppm as optimum concentrations of Mn.

Few acid soils supporting citrus trees are deficient in available manganese, according to Reitz et al. (*28*). Where definite deficiency symptoms persist, a soil application of $MnSO_4$ to supply 0.03 pound of MnO per box of fruit per year is suggested in Florida (*28*). Alternatively, a dilute foliar spray of $MnSO_4$ (15 to 25 pounds per 500 gallons) may be used as a cover spray. Reitz (*28*) pointed out that ''on calcareous or heavily limed acid soils, manganese should not be used in the fertilizer but applied as a foliar spray.''

Jacob and Uexkull (*20*) describe manganese deficiency in citrus in the following manner: ''manganese deficiency is also recognized by chlorosis of the intercostal areas of the leaf. In contrast to zinc, manganese deficiency has no effect on the size of the leaves, and it occurs more distinctly on the shaded foliage (north side). Manganese deficiency may occur equally on the young and old leaves, and this helps to distinguish it from magnesium deficiency which is only found on the old leaves. Manganese deficiency occurs most frequently on over-limed soils. The treatment consists of the application of 200 to 1,000 grams of $MnSO_4$ per tree. Spraying is more effective on soils having a pH over 7.''

According to Chapman et al. (*10*) , the zinc requirement of citrus trees closely approximates that of manganese. They offer a range of 20 to 80 ppm as normal for the element, with 15 ppm constituting a deficiency and anything above 100 ppm as probably excessive. The satisfactory range of zinc in citrus leaves in Florida has been shown to reach from 20 to 50 ppm (*28*). However, the citrus trees in California may show a much wider range in foliar zinc and still grow and produce well, according to Embleton et al. (*16*), who consider the values of 25 to 100 ppm as optimum and those concentrations above 300 ppm as too high.

In the words of Jacob and Uexkull (*20*), "zinc deficiency is characterized by typical discoloration of the leaves, which is known as 'Frenching,' 'mottle-leaf,' or 'foliocellosis.' In zinc deficiency the chlorophyll disappears between the veins which retain their dark-green color while the chlorotic areas become whitish-yellow. Oranges are more susceptible to zinc deficiency than other varieties of citrus. Zinc deficiency occurs, above all, on over-limed or extremely acid soils and often cannot be rectified by applications to the soil. The usual practice is to spray the foliage with zinc sulphate or zinc oxide mixed with burnt lime." The Florida research group (*28*) has also found foliar sprays to be the preferable method of correcting zinc deficiency. They note that "when zinc deficiency symptoms appear, zinc should be applied in a nutritional spray, in either the dormant or preferably the post-bloom period. Spraying with zinc every year is necessary only when zinc deficiency symptoms appear in the foliage. Corrections of moderate or severe zinc deficiency may require more than one spray in the same year."

According to Chapman et al. (*12*), iron is the trace element required by citrus trees in the largest amounts. They offer a range of 70 to 200 ppm as normal for healthy trees, and no concentration is suggested by them as excessive in citrus. Embleton et al. (*16*) prefer concentrations of foliar iron within the range of 60 to 120 ppm, while the optimum amount in Florida trees has been found to be 40 to 60 ppm (*28*). As pointed out by Jacob and Uexkull (*20*), iron deficiency usually occurs on over-limed soils (or those that are naturally alkaline), and in the initial stages it is easily confused with manganese deficiency because the veins, remaining dark-green in color, stand out like a network from the otherwise chlorotic leaf. "With acute deficiency, the young leaves become completely yellow and are shed prematurely. Until recently it was difficult to combat iron deficiency on alkaline soils because, in contrast to the other trace elements, spraying the leaves of citrus trees with iron had little effect. Moreover, soluble compounds of iron are more rapidly fixed in such soils than they can be taken up by the roots. Now, use is being made on an increasing scale of iron-chelate (iron chelated with ethylenediamine-tetra-acetic acid or other chelating agents)."

Boron is needed by citrus plants in concentrations of 20 to 100 ppm in the leaves, according to Chapman et al. (*12*). They caution that levels of 200 ppm are excessive and, as in the case of excessive manganese at this level, may cause plant damage. Embleton et al. (*16*) agree that 31 to 100 ppm of B is the optimum range for citrus leaves but specify that the foliage may tolerate concentrations of 260 ppm before phytotoxicity begins. The Florida research group (*28*) likewise offer a range of 40 to 100 ppm as satisfactory for foliar boron in citrus.

Boron deficiency symptoms of citrus have been characterized by Jacob and Uexkull (*20*) as follows: "boron deficiency appears chiefly on the young leaves and twigs, which roll up together, wilt, have a brownish color, and are readily dropped. The veins of the leaves are often thickened, chlorotic, and cracked. Gummosis occurs on the trunk, and parts of the branches die back. Boron-deficient fruits are small, malformed, and have brown mucilaginous discolorations on the skin. Mucilaginous formations may also occur elsewhere in the fruit.

"Boron deficiency is found both on acid and on alkaline soils, and it is often induced by long, dry periods. As a remedy, borax can be used in the solid form (20 to 30 kilograms per hectare or 18 to 27 pounds per acre), or the leaves can be sprayed with a 1 percent solution. An excess of boron is extremely toxic."

To correct boron deficiency of citrus under Florida conditions, Reitz et al. (*28*) suggest that boron (B_2O_3) be applied in the fertilizer at one hundredth the nitrogen application rate. An alternative remedy suggested is to apply soluble borate sprays at the rate of 1.67 pounds of 46 percent B_2O_3 material per 500 gallons of solution or 1.25 pounds of 58 to 66 percent material per 500 gallons. If deficiency symptoms persist, the rates may be doubled for a few applications (*28*).

Most authorities concur that the copper requirement of citrus trees is relatively low; in fact, molybdenum is the only element for which the need is smaller. Chapman et al. (*12*, *13*) specify a range of 4 to 10 ppm as normal for citrus leaves. Toxicity levels begin at 15 ppm in the view of this group. This same range for copper concentration is suggested by the Florida group led by Reitz (*28*). However, according to Embleton et al. (*16*), the optimum range is 5 to 16 ppm in California citrus leaves, and 22 ppm is considered excessive.

Jacob and Uexkull (*20*) explain that "copper deficiencies may occur on all soils, but most frequently they are found on virgin soils with a high humus content. Copper excess is found mostly on acid, light, slightly buffered soils and is indicated by cracking of the bark, gummosis, leaf fall, and, in certain circumstances, by the death of the tree. Copper excess, therefore, is considerably more dangerous than copper deficiency. In many fungicides, copper sulphate is present in sufficient quantity to control copper deficiency. From 200 to 400 grams of copper sulphate per tree (soil application) is adequate in most cases to remedy the deficiency."

Under Florida conditions, Reitz (*28*) observes that "copper is usually applied in fertilizer as copper sulphate or copper oxide. Most of the applied copper accumulates in the topsoil. Excess copper depresses growth and induces iron chlorosis. Soils that contain approximately 50 pounds of copper per acre 6 inches of soil need no copper in the fertilizer. Sufficient copper usually will be applied in the first 10 years of a young grove if the fertilizer contains about 0.25 unit of CuO.

"Copper sprays (3.75 pounds of Cu per 500 gallons) are effective in correcting copper deficiency. In addition, they provide very valuable fungicidal control of greasy spot, scab, and melanose."

Molybdenum, being the most dilute nutrient element in citrus leaf tissue, is difficult to measure accurately in normal, healthy plants. Chapman et al. (*12*) advanced values of 0.2 to 1 ppm as proper for citrus foliage, while Embleton et al. (*16*) consider the range of 0.1 to 3 ppm as optimum. The latter group has found that any level above 100 ppm of the element is excessive.

Foliar sprays of molybdenum are recommended by Reitz et al. (*28*) to correct the deficiency, which is commonly known as "yellow spot." "These symptoms usually appear in late summer and are occasionally severe in trees on grapefruit rootstock. Trees showing mild symptoms should be sprayed with a solution containing 5 ounces of sodium molybdate in 500 gallons, and in severe cases 10 ounces should be used. Application of molybdenum sprays should be made in spring or summer, since sprays applied in the fall may not be effective during the current year. In correcting yellow spot it is especially important that the soil reaction be adjusted to pH 6.0 or above."

Some experimental work has been conducted on the nutrition and fertilization of navel oranges grown under Louisiana conditions. In the early studies of the 1930's and 1940's by Miller and Kimbrough (*22*), it was found that trees located in the southern part of Plaquemines Parish responded to phosphorus and potassium in the fertilizer as well as to nitrogen, even on the relatively fertile alluvial soils of the Mississippi River. Several individual experiments were conducted, both with navel oranges and Satsumas, in which benefits from the use of complete fertilizer applied in late winter were clearly demonstrated. Furthermore, the feasibility of a summer application (July) of nitrogen, in addition to complete fertilizer, was also substantiated.

Fruit quality studies included in the work by Miller and Kimbrough (*22*) showed that nitrogen applied alone was detrimental in terms of earliness of maturity, skin color and thickness, percentage of juice in the fruit, and soluble solids/acid ratio. These undesirable effects were overcome by using balanced rates of phosphorus and potassium along with nitrogen in the fertilizer (winter application).

Since that time, further research by Brown et al. (*6*) has added credulence to the early findings (*22*) and has provided additional information on the appropriate ratios of N-P_2O_5-K_2O as well as rates of fertilizer that should be applied to Washington navel orange trees and Satsumas growing under southern Louisiana conditions.

The study reported here was undertaken to investigate more thoroughly the impact of individual nutrients applied at different rates, both individually and collectively (in a grade), on the long-term growth, production, and quality of Washington navel oranges. The interaction between the levels of fertilizer phosphorus and that furnished by the soil was to be studied closely in this experiment, as were those factors involved in the potassium nutrition of the trees. Also, an attempt was made to control the soil pH and extractable calcium level so their effects and possible interaction with applied nutrients might be studied.

Materials and Methods

During the 1964 growing season, a site was selected on the Plaquemines Parish Experiment Station, Port Sulphur, for establishment of a nutrition study with Washington navel oranges. The area is adjacent to the Mississippi River levee, and soil texture varies from silt loam to silty clay loam within short distances. This particular soil has been classified as a Commerce, interspersed with smaller areas of the Mhoon series. The soil was laid off in 30-foot rows that were ridged up as high as possible with conventional equipment. During the 1964 season, the rows were fallow plowed as often as necessary to control weeds and to establish good tilth in the soil in preparation for planting orange trees the following winter.

A supply of Washington navel orange trees was produced during the 1964 growing season by budding scionwood from an established tree on the station onto seedling rootstocks of the *Citrus trifoliata* variety. In the winter of 1964, these small trees were removed from the nursery row and transplanted into the experimental site. They were spaced 15 feet apart on 30-foot rows, comprising a total of 15 trees on each of 16 rows. No fertilization was used in the 1965 season, except that each tree received 0.04 pound of nitrogen in July in the form of ammonium nitrate.

An experimental design was developed in 1965 that would fit into the experimental area already planted. The main plot treatments consisted of soil amendment applications involving either lime (calcite) applications to maintain the soil pH above 6.5 or sulphur applications to control the soil pH in the range of 6 to 6.5. These two treatments were paired in each block (replication). Within each block a series of fertilizer treatments was arranged including (1) nitrogen applied alone at increasing rates, (2) nitrogen and phosphorus applied together at increasing rates, and (3) nitrogen, phosphorus, and potassium applied together at increasing rates. The complete fertilizer treatments were applied as an 8-12-8 grade, since previous research results (*6*) had indicated this ratio was the most effective under Louisiana conditions. Each plot contained three trees and was replicated four times in a complete block, split-plot design.

In August of 1965 and in August of alternate years thereafter, a representative soil sample was taken from each plot for extractable nutrient and pH determinations. Four borings 12 inches deep around the dripline of each tree (12 borings per sample) constituted a sample. The samples were analyzed in the Louisiana Soil Testing Laboratory by Brupbacher et al. (*8*) using standard methods of analysis (*7*). The results of these analyses served as a guideline for subsequent soil amendment applications to each plot.

During the first week of August every year, beginning in 1965, a foliage sample representative of each plot was taken from the trees. The leaves included in the sample were from the center of the shoots of the spring flush of growth. They were taken at random, 33 from each tree, so that a plot foliar sample contained 99 leaves. The leaves were washed in a mild detergent solution, rinsed twice in distilled water, and dried at 70°C for 72 hours. Then they were ground in a Wiley No. 1 mill to pass a 20-mesh screen and were analyzed by the staff of the Louisiana Feed and Fertilizer Laboratory, using methods outlined by A.O.A.C. (*3*).

The first soil amendment applications were made to the plots indicated by the soil tests in the summer of 1965. Then, in the winter of 1965-66, the first applications of the experimental fertilizers were made (February, 1966). The nutrient carriers used were ammonium nitrate (33.5 percent), diammonium phosphate (18-46-0), and muriate of potash (60 percent K_2O). They were weighed out and hand-mixed immediately prior to application. The specific treatment given to each plot is shown in Table 1. The fertilizer was broadcast under the tips of the branches in a wide band and disked into the soil 3 to 4 inches deep. This procedure was followed annually throughout the research period. Weeds were controlled under the trees by annual applications of Bromacil in late winter, and the area between the rows was kept closely mowed. Diseases and insects were controlled at all times with recommended pesticides, and the trees grew rapidly and produced good yields.

Table 1.—Soil amendments used in main plots and fertilizer treatments used in subplots of each block

Fertilizer treatment[1]	Soil amendment	
	Lime[2]	No lime[3]
0-0-0	*	*
8-0-0 (1)[4]	*	*
8-0-0 (1.5)	*	*
8-0-0 (2)	*	*
8-12-0 (1)	*	*
8-12-0 (1.5)	*	*
8-12-0 (2)	*	*
8-12-8 (1)	*	*
8-12-8 (1.5)	*	*
8-12-8 (2)	*	*

[1] Applied broadcast under the spread of the branches in February and disked lightly into the soil. Each tree also received .04 lb. of N per year of age in July.

[2] Limed to a soil pH above 6.5 and/or extractable calcium above 3,200 ppm.

[3] No lime applied, but sulphur was used on some plots to maintain a soil pH of about 6.0 to 6.5.

[4] Numbers in parentheses denote pounds of fertilizer applied per tree per year of age.

Measurements were made periodically of the growth of each tree in terms of increases in trunk circumference at a point about 6 inches above the bud union with the rootstock. The increase for each tree was combined with that of the two other trees in the same plot so that an average per tree could be determined. Results of these growth measurements are shown in Table 2.

The first fruit of a measurable quantity was obtained from these trees in the winter of 1967 (December). After that, yields became progressively greater each year, with that from some treatments gaining more than others. The fruit was harvested each year during the month of December, at the peak of maturity and at the time when the demand is highest. At this time a representative sample (10 oranges) was taken from each tree (30 oranges per plot) in order to study any possible effects of soil amendments or fertilizer treatments on fruit quality. The quality factors involved in this work were: fruit weight, juice content (%), soluble solids (%), titratable acids (%), solids/acid ratio, rind thickness, and rind color. The samples of 30 oranges each for quality studies were taken to Baton Rouge for analysis. The average weight per orange was determined for each plot. Thickness of the orange rind at the equator was measured with calipers graduated in millimeters. The juice from the 30-orange sample was extracted with a

Table 2.—Effects of fertilizer and lime treatments on the increase in trunk circumference of Washington navel orange trees during a 12-year period, 1965-76

Fertilizer treatment[1]	Lime treatment		Fertilizer average
	None[2]	Lime[3]	
	Increase in circumference (cm)[4]		
0-0-0	47.7	45.2	46.4
8-0-0 (1)[5]	52.2	51.0	51.6
8-0-0 (1.5)	49.7	47.7	48.9
8-0-0 (2)	48.7	46.5	47.6
8-12-0 (1)	51.7	49.7	50.7
8-12-0 (1.5)	52.5	50.0	51.2
8-12-0 (2)	50.5	49.7	49.9
8-12-8 (1)	52.0	51.0	51.5
8-12-8 (1.5)	54.2	53.0	53.6
8-12-8 (2)	55.5	54.0	54.7
Lime average	51.5	49.8	

For comparing fertilizer averages, H.S.D. @ .05 = 1.4, @ .01 = 1.6.
For comparing lime averages, H.S.D. @ .05 = 0.6, @ .01 = 0.7
F value for interaction of fertilizer x lime—ns (.05).

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[1] Applied broadcast under the tips of the branches in February and disked lightly into the soil. Each tree also received .04 lb. of N per year of age broadcast under the branches in July as ammonium nitrate.

[2] Soil pH maintained at about 6.0 to 6.5.

[3] Soil pH maintained above 6.5 and/or extractable calcium above 3,200 ppm.

[4] Increases from the time trees were planted until final measurements were made (12 years).

[5] Numbers in parentheses denote pounds of fertilizer applied per tree per year of age.

Sunkist Type 6 juicer and strained, and the percentage of juice in the fruit was calculated.

The pH of the juice was determined by using a glass electrode pH meter, and the percentage of soluble solids (sugars) was measured by use of an Abbe' refractometer. The content of titratable acidity was determined by titration of a 10-milliliter juice sample in 100 milliliters of distilled water. The acid was titrated with 0.1 N NaOH to a pH of 7.0, using a pH meter as reference. The solids/acid ratios were then calculated.

Before juice extraction, each orange was cleaned by hand and rind color was determined with a Gardner color and color difference meter using a white standard tile (L = 91.6, a = −1.3, b = 0.1) as a reference. The effects of the treatments on fruit production are shown in Table 3, while the influence on fruit quality is shown in Table 23.

It was observed during this study that treatment factors were exerting important influences on other responses by the trees. For example, clearcut differences were shown among trees in the extent of cold damage sustained by young leaves, flowers, and twigs. The data obtained pertaining to this observation are shown in Table 4. Also, a difference in the amount of fruit that split and fell from the tree prematurely was apparently more closely associated with some of the treatments than with others. Measurements of these responses are shown in Tables 5 and 6. Further, a definite effect of amendment and fertilizer was shown in the degree of expression of manganese and zinc deficiency symptoms in the foliage. These effects are shown in Tables 14, 15, and 16.

Results and Discussion

All trees in the planting grew well throughout the 15 years of the study; however, some trees grew more than others. This is shown in Table 2 in terms of trunk circumference. Trees receiving nitrogen, phosphorus, and potassium at the heaviest rate (2 pounds of 8-12-8 per tree per year of age) achieved the most growth. The complete fertilizer treatments used at lighter rates were less effective; however, the overall superiority of the complete fertilizer to those containing only one or two elements was clearly indicated. The use of heavy rates of nitrogen alone appeared to be relatively ineffective, and the application of lime to maintain a high soil pH was detrimental to tree growth.

Foliage on all of the trees retained a good, dark-green color during the entire study, with a few exceptions in certain plots where symptoms of manganese and/or zinc deficiency were shown. These abnormalities will be discussed in greater detail later.

After a couple of years of growth, a few fruit were first borne by these trees in the 1967 season. The fruit were harvested and weighed, and the results appear in Table 3 in which production values are expressed as

Table 3.—Effects of soil amendment and fertilizer applications on marketable yield of Washington navel oranges, 1967-79

Soil amendment and fertilizer[1]	Pounds/tree/season														
	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	$\overline{X}$	Avg.[2]
No lime[3] 0-0-0	23	29	128	51	202	159	176	152	196	142	233	270	329	161	
Lime[4] 0-0-0	9	14	112	46	212	123	135	110	190	105	183	276	286	139	
Avg.	16	21	120	49	207	141	156	131	193	124	208	273	308		150f
No lime 8-0-0 (1)[5]	29	33	183	112	330	283	304	211	250	276	319	393	423	234	
Lime 8-0-0 (1)	25	48	135	73	296	232	252	183	231	266	284	375	449	219	
Avg.	27	40	159	93	313	258	278	197	241	271	301	384	436		227c
No lime 8-0-0 (1.5)	17	40	136	97	249	302	286	210	244	250	296	335	364	217	
Lime 8-0-0 (1.5)	25	34	136	61	261	278	239	198	235	235	235	359	335	202	
Avg.	21	37	136	79	255	290	263	204	240	243	266	347	350		210d
No lime 8-0-0 (2)	20	46	130	71	260	215	244	150	205	193	283	316	334	190	
Lime 8-0-0 (2)	23	25	123	68	250	192	219	140	190	189	209	364	421	186	
Avg.	22	36	127	70	255	204	232	145	198	191	246	340	378		188e
No lime 8-12-0 (1)	21	27	128	65	273	289	325	237	245	366	342	386	408	239	
Lime 8-12-0 (1)	31	46	166	77	296	234	277	224	257	328	310	321	370	227	
Avg.	26	37	147	71	285	262	301	231	251	347	326	358	389		233c
No lime 8-12-0 (1.5)	26	35	148	68	287	317	369	295	270	323	412	393	476	263	
Lime 8-12-0 (1.5)	31	52	164	125	314	273	291	256	272	271	335	326	465	244	
Avg.	29	44	156	97	301	295	330	276	271	297	374	360	471		254b
No lime 8-12-0 (2)	30	38	125	47	253	296	319	275	260	291	423	336	395	238	
Lime 8-12-0 (2)	15	43	123	73	234	286	282	243	248	260	384	318	421	225	
Avg.	23	41	124	60	244	291	301	259	254	276	404	327	408		232c
No lime 8-12-8 (1)	22	40	150	83	313	283	327	312	290	413	380	375	443	264	
Lime 8-12-8 (1)	17	25	133	70	312	260	250	271	243	360	390	290	446	236	
Avg.	20	32	142	77	313	272	289	292	267	386	385	332	445		250b

(Continued)

Table 3.—(Continued)

Soil amendment and fertilizer[1]	Pounds/tree/season 1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	$\overline{X}$	Avg.[2]
No lime 8-12-8 (1.5)	19	42	112	63	272	315	352	331	328	469	456	328	471	274	
Lime 8-12-8 (1.5)	30	47	106	59	256	275	325	289	270	423	399	366	454	254	
Avg.	25	44	109	61	264	295	339	310	299	446	428	347	463		264b
No lime 8-12-8 (2)	26	53	142	80	260	296	359	396	340	550	503	338	491	295	
Lime 8-12-8 (2)	23	45	133	95	284	247	320	361	288	490	460	304	496	273	
Avg.	25	49	138	88	272	272	340	379	314	520	482	321	494		284a
Season avg.—no lime[2]	23	38	138	74	270	276	306	257	263	327	365	347	413	238a	
Season avg.—lime[2]	23	38	133	75	272	240	259	228	242	293	319	331	414	220b	
Season avg.	23	38	136	75	271	258	283	242	253	310	342	339	414		229

[1] Applied broadcast under the tips of the branches in February and disked lightly into the soil. Each tree also received .04 lb. of N per year of age in July.

[2] Averages followed by different letters are different at the .01 level of probability.

[3] Soil pH maintained at about 6.0 to 6.5. Some plots received sulphur applications broadcast evenly over the entire plot.

[4] Limed to the extent necessary to maintain soil pH above 6.5 and/or extractable calcium above 3,200 ppm.

[5] Numbers in parentheses denote pounds of fertilizer applied per tree per year of age.

Table 4.—Effects of fertilizer and lime treatments on the extent of cold[1] damage shown by Washington navel orange trees

Fertilizer treatment[2]	No lime					Lime					Fertilizer average
	1968	1969	1973	1977	Avg.	1968	1969	1973	1977	Avg.	
	Cold damage rating[3]										
0-0-0	1.48	1.50	0.40	0.75	1.03	1.23	1.80	1.40	1.17	1.40	1.22
1 lb. 8-0-0/tree/year of age	1.28	1.90	0.20	1.50	1.22	1.30	2.40	0.40	1.08	1.30	1.26
1.5 lbs. 8-0-0/tree/year of age	1.45	3.00	0.40	1.08	1.48	1.30	2.70	0.90	0.92	1.46	1.47
2 lbs. 8-0-0/tree/year of age	2.40	2.80	0.70	0.67	1.64	1.23	3.10	2.20	0.92	1.86	1.75
1 lb. 8-12-0/tree/year of age	1.45	1.40	0.10	1.34	1.07	1.80	1.50	1.20	1.42	1.48	1.28
1.5 lbs. 8-12-0/tree/year of age	1.55	2.00	0.20	0.67	1.11	1.23	1.60	1.70	1.09	1.41	1.26
2 lbs. 8-12-0/tree/year of age	1.45	2.30	0.60	0.92	1.32	1.53	2.40	0.40	0.84	1.29	1.31
1lb. 8-12-8/tree/year of age	1.48	1.40	0.20	0.50	0.90	1.40	1.70	0.70	0.59	1.10	1.00
1.5 lbs. 8-12-8/tree/year of age	1.05	1.90	0.40	0.50	0.96	1.65	1.20	0.60	1.68	1.28	1.12
2 lbs. 8-12-8/tree/year of age	1.23	1.20	0.10	1.08	1.90	2.03	1.20	0.50	1.17	1.23	1.07
Amendment average					1.16					1.38	
H.S.D. (0.05)	1.02	0.94	0.64	0.94		1.02	0.94	0.64	0.94		

For comparing fertilizer averages, H.S.D. @ .05 = 0.34.
F value for fertilizer average—ns (.05).
F value for amendment x fertilizer interaction—ns (0.05).

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[1] Low temperatures recorded at the orchard site were 26°F on March 1, 1968; 19°F on January 8, 1969; 21°F on January 13, 1973, and 19°F on February 10, 1977.

[2] Applied broadcast under the tips of the branches in February and disked lightly into the soil. Each tree also received .04 lb. of N per year of age broadcast under the branches in July as ammonium nitrate.

[3] Based on a visual scale of 0 = no damage to 5 = severe damage to young terminals and flower buds.

Table 5.—Effects of fertilizer and lime treatments on the number of split fruit produced by Washington navel orange trees, September 1971

Fertilizer treatment[1]	Lime treatment None[2]	Lime treatment Lime[3]	Fertilizer average
	No. split fruit[4]		
0-0-0	3.1	3.0	3.1
1 lb. 8-0-0/tree/year of age	2.7	2.3	2.5
1.5 lbs. 8-0-0/tree/year of age	4.2	2.8	3.5
2 lbs. 8-0-0/tree/year of age	1.3	4.2	2.8
1 lb. 8-12-0/tree/year of age	1.2	4.5	2.9
1.5 lbs. 8-12-0/tree/year of age	1.3	4.2	2.8
2 lbs. 8-12-0/tree/year of age	1.1	0.8	1.0
1 lb. 8-12-8/tree/year of age	0.9	1.6	1.3
1.5 lbs. 8-12-8/tree/year of age	0.6	0.7	0.7
2 lbs. 8-12-8/tree/year of age	2.0	1.2	1.6
Lime average	1.8	2.5	

For comparing fertilizer averages, H.S.D. @ .05 = 2.8
F value for lime treatments—ns (.05).
F value for fertilizer x lime treatment interaction—ns (.05).

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[1] Applied broadcast under the tips of the branches in February and disked lightly into the soil. Each tree also received .04 lb. of N per year of age broadcast under the branches in July as ammonium nitrate.

[2] Soil pH maintained at approximately 6.0 to 6.5.

[3] Soil pH maintained above 6.5.

[4] Average number of split fruit per tree.

Table 6.—Effects of fertilizer and lime treatments on the number of split fruit produced by Washington navel orange trees, October 1972

Fertilizer treatment[1]	Lime treatment None[2]	Lime treatment Lime[3]	Fertilizer average
	No. split fruit[4]		
0-0-0	21.5	10.5	16.0
1 lb. 8-0-0/tree/year of age	18.3	16.3	17.3
1.5 lbs. 8-0-0/tree/year of age	37.8	25.5	31.6
2 lbs. 8-0-0/tree/year of age	31.3	24.5	27.9
1 lb. 8-12-0/tree/year of age	30.5	27.5	29.0
1.5 lbs. 8-12-0/tree/year of age	20.3	14.3	17.3
2 lbs. 8-12-0/tree/year of age	24.5	27.0	25.8
1 lb. 8-12-8/tree/year of age	27.8	18.5	23.1
1.5 lbs. 8-12-8/tree/year of age	24.3	24.5	24.4
2 lbs. 8-12-8/tree/year of age	36.8	27.5	32.1
Lime average	27.3	21.6	

For comparing fertilizer averages, H.S.D. @ .05 = 17.7
For comparing lime averages, H.S.D. @ .05 = 7.9.
F value for fertilizer x lime interaction—ns (.05).

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[1] Applied broadcast under the tips of the branches in February and disked lightly into the soil. Each tree also received .04 lb. of N per year of age broadcast under the branches in July as ammonium nitrate.

[2] Soil pH maintained at approximately 6.0 to 6.5.

[3] Soil pH maintained above 6.5.

[4] Average number of split fruit per tree.

average pounds per tree. Yields were so scant during the first season that no association between fertilization and production was indicated. Fruit harvested from each plot was transported to the Department of Horticulture laboratory at Baton Rouge for fruit quality determinations. This procedure was followed each year.

In the 1968 season, yields increased somewhat above those of the previous year; however, no major differences in production were noted that could be attributed to any of the treatments.

A remarkable increase in yields occurred in 1969, with more than 100 pounds of fruit being harvested from each tree. Still, even though some of the trees apparently produced more fruit than others, there were no significant effects of fertilizer or lime applications.

During the 1970 season none of the trees produced as much fruit as they had in 1969. Yield was reduced by as much as 50 percent in many cases. This reduction was not associated with any particular treatment and cannot be explained on the basis of cold damage to flowers in the spring or on unusually severe weather conditions during the growing season. It may be speculated that young navel orange trees in rapid growth stages may show some tendency toward alternate bearing, as is common with many other fruit species.

Following the light crop in 1970, a relatively heavy crop was produced by all trees in the 1971 season. For the first time, the effectiveness of fertilization on yield was indicated, with the low rate of nitrogen alone, especially without lime, being about as effective as any other treatment. At this stage of growth and production the trees evidently were still absorbing sufficient amounts of phosphorus and potassium from the soil to meet their needs.

Some important differences in production began to appear in the 1972 season. The unfertilized plots fell far behind all the others, and the use of nitrogen alone, at either light or heavy rates, began to lose its equality in effectiveness with the treatments that also contained phosphorus or phosphorus and potassium. Another important factor in the 1972 data is that the more effective fertilizer treatments showed yield increases above those of the previous season while some of the other treatments showed reductions in yield, again indicating a tendency toward biennial bearing. Also, even in the more effective treatments a detrimental effect of lime applications was beginning to appear as a trend.

In 1973, the yield from the unfertilized trees, while apparently increasing somewhat over the previous year, still lagged far behind that of any of the fertilized plots. The high soil pH resulting from lime applications continued to exert a depressing effect on yield, regardless of the fertilizer application, and the use of high rates of nitrogen were less beneficial than lower rates when the element was applied alone. The most marked responses were obtained from complete fertilizer applications without lime, and the heavier the rate of fertilization the higher the yield.

The 1974 season was another relatively "light" crop year. This was true for all of the treatments with the exception of those with complete fertilizer. Production from these plots continued along a level comparable to or above that of the preceding season, thus preventing the appearance of alternate bearing tendencies in these treatments. The other treatments, showing reductions in yield from the 1973 season, were still allowing this biennial bearing tendency to be shown. The reduction in yield in the limed plots was consistent and of moderate magnitude in most cases.

Fruit production in the 1975 season was also below what might be expected on a linear scale of trees of this age, with the notable exception of the trees receiving complete fertilizer at a medium or heavy rate without lime applications. These trees produced about as much fruit as they had the year before (more than 300 pounds per tree) while the unfertilized trees produced less than 200 pounds. Yield levels of trees receiving only nitrogen or nitrogen and phosphorus were intermediate.

The 1976 season was a "heavy" crop year in that the most effective treatments (those containing all three fertilizer elements) produced very high yields. Trees receiving complete fertilizer at the heaviest rate produced 550 pounds of fruit per tree. The effect of even this treatment was reduced somewhat by the use of lime on the soil. This reduction by lime treatment was also shown for every other fertilizer treatment. The only other fertilizer treatments to exceed 400 pounds of fruit per tree were the complete fertilizer applications at the light rate (413 pounds of fruit) and the medium rate (469 pounds of fruit). The other trees receiving only nitrogen and phosphorus yielded something less than 400 pounds while the nitrogen-only treatments produced less than 300 pounds. In contrast, the unfertilized trees produced only a little more than 100 pounds, with the limed plots again producing the least.

Yields from most of the plots were higher in the 1977 season than they had been in 1976. Even the unfertilized trees showed considerable gains in production, but their output was still well below that of the fertilized trees, especially those receiving complete fertilizer at the highest rate and no lime. The yield in the latter plot was 503 pounds per tree, compared with 233 pounds from the unfertilized trees. Yields from the trees receiving the medium or lightest rate of complete fertilizer were also still high, as were those from trees receiving the heavier rates of nitrogen and phosphorus only. The use of nitrogen alone, at any rate, continued to be the most ineffective method of fertilization.

Yields from the various plots in 1978 were more nearly comparable than they had been since the earliest years of harvest. Some of the plots showed some reduction in yield while others made slight gains in production. During this season, the type of fertilization used had little effect on fruit production, but all fertilization systems were superior to no fertilization.

In 1979, the last year in which production data were obtained in this study, the response patterns to fertilizer applications established in the previous seasons continued to be shown. More specifically, the complete fertilizers applied at the heavier rate were still the most effective treatments (yields approached 500 pounds per tree), the use of nitrogen and phosphorus together were somewhat less effective but were still superior to nitrogen applied alone, and the lightest rate of nitrogen was more beneficial to yield than the heavier rates. The unfertilized trees were still clearly inferior in yield (producing only about 300 pounds per tree), and the effect of lime use was inconsistent among fertilizer treatments during this season.

In assessing the influence of type of fertilization and lime application during the 13-year production period, it is clear that fruit production was markedly affected by both of these variables, especially fertilization. The average yield for unfertilized trees (without lime) was 161 pounds per tree, while that for trees receiving 2 pounds of 8-12-8 per year of age was 295 pounds. Where nitrogen was applied alone, although some response was obtained, fruit production decreased linearly with rate of application. Increases were also obtained, but curvilinearly, where nitrogen and phosphorus were applied together without potassium. However, when all three fertilizer elements were applied together, the average yield increased linearly with rate of application and reached the maximum point noted in the study (295 pounds). With each fertilizer treatment the average yield was reduced by the use of the lime amendment. Actually, the average yield for the limed plots in the study was 220 pounds per tree as compared with 238 pounds per tree for the unlimed plots. In judging the overall effect of type of fertilization as an average of soil amendment plots, the superiority of the heavy rates of complete fertilizer was obvious (284 pounds per tree). Omitting potassium or potassium and phosphorus from the fertilizer caused a meaningful reduction in yield. Also, when nitrogen was used alone, the heavier rates were clearly less effective than the lighter rate although still somewhat better than no fertilizer at all.

The tendency of the trees, especially those receiving certain treatments, toward alternate bearing, or at least toward having low-crop years interspersed with high-crop years, was referred to previously. This tendency was almost wholly offset by the effects of the better fertilizer treatments on yield. This suggests that the reproductive physiology of the trees is influenced favorably when the tree is provided proper nutrition in the form of a balanced fertilizer at the proper rate. It may be surmised that low-crop years experienced during the study were caused by cold damage to flowers and tender apices during winter and early spring. But it should be noted that in those years when the temperature was low enough to cause some damage—1968, 1969, 1973, and 1977 (Table 4)—the trees produced considerably more fruit in each case than they had in the previous year. Thus, it appears the cold damage sustained by trees is not the explanation in this case for their tendency toward alternate bearing. Rather, as indicated by the progressive differences in yield data, the lack of proper nutrition in some of the trees as a result of inappropriate fertilization was a major factor influencing the tendency toward alternate bearing.

All trees in the study sustained some cold damage (Table 4). There was little difference in the extent of damage in any season due to fertilizer treatment, except that trees receiving only nitrogen appeared to be damaged more severely than the others in many cases. It is noteworthy that the trees receiving complete fertilizer but no lime showed the least damage. Also, in most cases, trees growing on limed soil apparently were somewhat more susceptible to cold injury than those grown on the more acid soil.

Information was obtained during the 1971 and 1972 seasons on the effects of fertilizer and lime treatments on the number of split fruit produced by the trees. In the 1971 season (Table 5), when this problem was minimal in all plots, there was some indication that trees receiving complete fertilizer, especially at the medium rate, produced less split fruit than those receiving other fertilizer applications or none. Use of lime apparently did not influence the production of split fruit. In the 1972 season (Table 6), when the number of split fruit was much higher in all plots, the effect of fertilizer was somewhat erratic, and no clear-cut pattern emerged. The difference indicated for the influence of lime was opposite to that of the previous year. Thus, no conclusions seemed warranted. In the past, experience with this phenomenon has shown it to be closely related to extremes in cyclic soil moisture rather than fertilization, in that the problem is aggravated by a long period of dry weather when the fruit is approaching maturity followed by heavy rainfall before harvest. Under these conditions the fruit evidently takes in moisture so rapidly that excessive pressure is exerted internally against the mature rind, causing the rind to separate along its weakest plane and thus ruining the fruit for market. Splitting of the fruit is often followed by its abscission from the tree.

The annual chemical analyses of the leaves showed the average nitrogen concentration of the foliage was affected appreciably by the different fertilizers (Table 7). However, no real effect of lime application on foliar N was shown. In general, the heavier the application of nitrogenous fertilizer the higher the concentration of foliar N. The most outstanding variation in the data was the difference in N levels among seasons, with this variation being manifested regardless of the fertilizer or lime treatment used. Yet, there was some difference in the degree of variation among fertilizer treatment effects in the different years, resulting in a significant interaction between these factors. The same inference may be drawn for the factors of lime application and season of sampling, since a true interaction was demonstrated here also. In general terms, it is noteworthy that the N concentrations in the foliage from all plots fell within the range considered satisfactory by other workers (*16, 20, 28*) and that the N level in the leaves did not decline greatly with age of the tree.

Table 7.—Effects of soil amendment and fertilizer applications on the nitrogen concentration in the leaves of Washington navel oranges

Soil amendment and fertilizer[1]	N concentration (% dry wt.)														
	1965	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	$\bar{X}$	Avg.[2]
No lime[3] 0-0-0	3.3	3.2	2.6	3.0	2.9	3.0	2.5	2.3	3.0	2.7	2.5	2.6	3.3	2.7	2.8	
Lime[4] 0-0-0	3.3	3.2	2.6	2.9	2.9	3.0	2.5	2.3	2.8	2.7	2.4	2.6	3.1	2.9	2.8	
Avg.	3.3	3.2	2.6	3.0	2.9	3.0	2.5	2.3	2.9	2.7	2.5	2.6	3.2	2.8		2.82de
No lime 8-0-0 (1)[5]	3.3	3.0	2.7	2.9	3.0	3.1	2.6	2.4	2.8	2.7	2.5	2.8	2.9	2.7	2.8	
Lime 8-0-0 (1)	3.3	3.1	2.6	3.0	2.9	3.0	2.6	2.3	2.9	2.6	2.5	2.7	3.1	2.7	2.8	
Avg.	3.3	3.1	2.7	3.0	3.0	3.1	2.6	2.4	2.9	2.7	2.5	2.8	3.0	2.7		2.80e
No lime 8-0-0 (1.5)	3.2	3.1	2.6	2.9	2.9	2.9	2.6	2.4	3.0	2.7	2.6	2.7	3.0	2.8	2.8	
Lime 8-0-0 (1.5)	3.3	3.1	2.7	2.9	2.9	2.9	2.6	2.4	2.9	2.6	2.5	2.9	3.0	2.9	2.8	
Avg.	3.3	3.1	2.7	2.9	2.9	2.9	2.6	2.4	3.0	2.7	2.6	2.8	3.0	2.9		2.82de
No lime 8-0-0 (2)	3.4	3.1	2.7	2.9	3.0	3.1	2.8	2.5	2.9	2.7	2.7	3.0	3.0	2.7	2.9	
Lime 8-0-0 (2)	3.3	3.1	2.8	3.0	3.1	3.0	2.7	2.4	2.9	2.7	2.6	2.8	3.1	2.9	2.9	
Avg.	3.4	3.1	2.8	3.0	3.1	3.1	2.8	2.5	2.9	2.7	2.7	2.9	3.1	2.8		2.88ob
No lime 8-12-0 (1)	3.1	3.0	2.7	3.0	2.9	3.1	2.5	2.4	2.9	2.8	2.5	2.9	3.0	2.8	2.8	
Lime 8-12-0 (1)	3.2	3.2	2.6	3.0	3.0	3.0	2.6	2.3	2.9	2.6	2.5	2.8	3.1	2.9	2.8	
Avg.	3.2	3.1	2.7	3.0	3.0	3.1	2.6	2.4	2.9	2.7	2.5	2.9	3.1	2.9		2.83cde
No lime 8-12-0 (1.5)	3.3	3.2	2.7	2.9	3.0	3.1	2.7	2.4	2.9	2.8	2.6	2.9	3.1	2.9	2.9	
Lime 8-12-0 (1.5)	3.2	3.2	2.7	2.9	3.0	3.1	2.6	2.4	2.9	2.7	2.6	2.8	3.1	2.9	2.9	
Avg.	3.3	3.2	2.7	2.9	3.0	3.1	2.7	2.4	2.9	2.8	2.6	2.9	3.1	2.9		2.86abc
No lime 8-12-0 (2)	3.3	3.2	2.7	3.0	3.0	3.0	2.7	2.5	3.0	2.8	2.8	3.0	3.0	2.9	2.9	
Lime 8-12-0 (2)	3.4	3.1	2.6	2.9	3.0	3.1	2.7	2.4	2.9	2.6	2.7	2.9	3.2	3.0	2.9	
Avg.	3.4	3.2	2.7	3.0	3.0	3.1	2.7	2.5	3.0	2.7	2.8	3.0	3.1	3.0		2.90ob
No lime 8-12-8 (1)	3.3	3.2	2.8	3.0	3.0	3.0	2.7	2.4	2.9	2.7	2.5	2.8	3.1	2.8	2.9	
Lime 8-12-8 (1)	3.3	3.1	2.7	2.9	3.0	3.0	2.6	2.4	2.9	2.7	2.5	2.8	3.1	2.9	2.9	
Avg.	3.3	3.2	2.8	3.0	3.0	3.0	2.7	2.4	2.9	2.7	2.5	2.8	3.1	2.9		2.85bcd

(Continued)

Table 7.—(Continued)

Soil amendment and fertilizer[1]	N concentration (% dry wt.)															
	1965	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	$\overline{X}$	Avg.[2]
No lime 8-12-8 (1.5)	3.2	3.2	2.8	3.0	2.8	3.1	2.6	2.4	3.0	2.7	2.6	2.9	3.1	2.9	2.9	
Lime 8-12-8 (1.5)	3.2	3.1	2.7	2.9	3.1	3.0	2.6	2.4	3.0	2.7	2.6	2.9	3.0	3.0	2.9	
Avg.	3.2	3.2	2.8	3.0	3.1	3.1	2.6	2.4	3.0	2.7	2.6	2.9	3.1	3.0		2.86abc
No lime 8-12-8 (2)	3.3	3.2	2.7	2.9	2.9	3.1	2.7	2.4	3.0	2.7	2.8	3.0	3.2	2.9	2.9	
Lime 8-12-8 (2)	3.3	3.1	2.6	2.9	3.0	3.0	2.7	2.5	3.0	2.7	2.6	3.0	3.1	2.9	2.9	
Avg.	3.3	3.2	2.7	2.9	3.0	3.1	2.7	2.5	3.0	2.7	2.7	3.0	3.2	2.9		2.96a
Season avg.—no lime[2]	3.3	3.1	2.7	3.0	2.9	3.1	2.6	2.4	2.9	2.7	2.6	2.9	3.1	2.8	2.86a	
Season avg.—lime[2]	3.3	3.1	2.7	2.9	3.0	3.0	2.6	2.4	2.9	2.7	2.6	2.8	3.1	2.9	2.84a	
Season avg.	3.3	3.1	2.7	3.0	3.0	3.1	2.6	2.4	2.9	2.7	2.6	2.9	3.1	2.9		2.86

[1] Applied broadcast under the tips of the branches in February and disked lightly into the soil. Each tree also received .04 lb. of N per year of age in July.

[2] Averages followed by different letters are different at the .01 level of probability.

[3] Soil pH maintained at about 6.0 to 6.5. Some plots received sulphur applications broadcast evenly over the entire plot.

[4] Limed to the extent necessary to maintain soil pH above 6.5 and/or extractable calcium above 3,200 ppm.

[5] Numbers in parentheses denote pounds of fertilizer applied per tree per year of age.

The phosphorus concentration of the foliage was also influenced by the type of fertilizer used but not by the lime application (Table 8). The average P levels in the foliage reflected the positive effects of using complete fertilizer at a relatively high rate as compared with N alone, with the control (which was producing far less growth and fruit) showing the highest concentration of P. One of the principal factors responsible for variations in P concentration was season of growth. The variation was sporadic among years and possibly could be correlated with variations in growing conditions. The P concentration in all samples apparently was such that a serious deficiency of the element in the leaves was very unlikely, according to authorities from other areas (*16, 20, 28*). The level of this element also remained about as high in the older trees as it was in the younger ones. Evidently, navel orange trees require much less P than N. It should be kept in mind that although levels of extractable P in the soil were high even in the control plots (Table 20), the trees responded well to P and K in the fertilizer in terms of growth and yield (Tables 2 and 3). The inference from these data is that total uptake of P and K was promoted by the use of complete fertilizer.

Use of fertilizer had some effect on the concentration of potassium in the foliage (Table 9), but no effect of lime was seen. The lowest K concentration occurred where the heaviest rate of N was applied. Once again, the control plants accumulated the most K, and those receiving complete fertilizer were intermediate. The largest variations noted for this element occurred rather inconsistently among seasons, indicating the influence of natural growing conditions. With few exceptions, the levels of K found in these samples fell within the range of 1.3 percent to 1.5 percent or above, the concentration considered adequate by Chapman (*11, 12*) and others (*16, 20, 28*). All plots contained large amounts of extractable K in the soil, (Table 21), yet trees receiving complete fertilizer made considerably more growth and had higher yields than those receiving N alone, N and P, or no fertilization (Tables 2 and 3), again indicating the stimulation in total uptake of P and K due to use of the complete fertilizer.

The accumulation of calcium in the leaves appeared to be moderately affected by the type of fertilizer used but not by the lime application (Table 10). The latter point is not surprising in view of the type of soil involved (high buffer capacity) and the small changes in the soil reaction brought about by the relatively light applications of lime made to the various plots (Table 17). Furthermore, lime applications caused only slight increases in the levels of easily extractable (available) calcium in the soil (Table 18). As was the case with the other elements, the most prominent variation in foliar calcium was that occurring among seasons. The range of about 2 percent to 5 percent that was observed precludes a really plausible explanation, but presumably some of this difference is attributable to variations in environmental conditions not controlled during experimentation. Other workers (*12, 16, 20, 28*) have found similarly wide ranges in the calcium concentration in orange tree leaves.

The magnesium accumulated by the leaves in this study was influenced only by season of growth, as shown in Table 11. Neither fertilization nor lime application had any bearing on the concentration of this element. Only calcitic lime was used to raise the pH of the limed plots. Furthermore, the soil in all plots contained high amounts of extractable magnesium (Table 19). In general, the foliar concentration of Mg ranged from about .3 percent to .4 percent, the levels advocated by other authorities (*11, 12, 16, 20, 28*) as normal for citrus trees. In this study, the seasonal variation of Mg was not nearly as large as that of most other elements.

The manganese concentration in the leaves was negatively affected by lime applications (Table 12). Also, there was evidence that the heavier rates of fertilization (particularly with complete fertilizer) increased the manganese accumulation by leaves, especially as the trees increased in age. This deduction is supported by the significant interaction of fertilizer treatment and season. The effect of lime was not constant for all seasons either, as shown by the significant interaction of these two factors. The singular effect of lime application was to reduce the amount of manganese accumulated by the leaves, presumably by raising the soil pH enough to reduce the availability of soil manganese to the trees. In this study, the foliar Mn concentration varied generally from 15 to 45 ppm, with a few plots in certain seasons dropping as low as 6 ppm and a few others rising above 50 ppm. These values may be compared with those of other workers (*12, 16, 28*) who suggest that 20 ppm is the level at which Mn deficiency begins in citrus leaves. If this is true for Louisiana conditions, it would explain the Mn deficiency symptoms on leaves containing less than 20 ppm of Mn that were taken from some of the plots (Table 12). The upper limit of safe concentration as suggested by the workers above ranges from 80 to 200 ppm of Mn, with the actual limit varying considerably with individual workers. All of the samples in this study were well below these levels; accordingly, no phytotoxicity symptoms of manganese were observed. (Samples were not analyzed for Mn in 1969 or 1970.)

The accumulation of zinc in leaves was not consistently affected by the type of fertilization or the lime application (Table 13). The level of zinc was remarkably similar in all samples, with the notable exception of the 1977 season and to some extent the 1979 season. An increased accumulation during those seasons was probably related to the use of Zineb foliar spray in those years. During the other seasons, most samples ranged from 10 to 25 ppm of Zn; however, some plots did vary within treatments from year to year, from the standpoints of both fertilizer treatment and lime, as shown by significant interactions of these factors. The normal level of zinc found in healthy citrus trees in other areas has been shown to range from 20 to 100 ppm (*10, 16, 28*), with 15 ppm as the concentration at or below which Zn

Table 8.—Effect of soil amendment and fertilizer applications on the phosphorus concentration in the leaves of Washington navel oranges

Soil amendment and fertilizer[1]	P concentration (% dry wt.)															
	1965	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	$\overline{X}$	Avg.[2]
No lime[3] 0-0-0	.20	.23	.17	.24	.21	.25	.14	.18	.18	.21	.24	.17	.21	.19	.20	
Lime[4] 0-0-0	.22	.22	.16	.23	.21	.24	.15	.16	.18	.20	.27	.17	.22	.21	.20	
Avg.	.21	.23	.17	.24	.21	.25	.15	.17	.18	.21	.26	.17	.22	.20		.20a
No lime 8-0-0 (1)[5]	.21	.21	.18	.23	.20	.24	.13	.15	.16	.21	.21	.15	.21	.17	.19	
Lime 8-0-0 (1)	.21	.24	.17	.22	.20	.24	.13	.14	.18	.22	.22	.15	.20	.18	.19	
Avg.	.21	.23	.18	.23	.20	.24	.13	.15	.17	.22	.22	.15	.21	.18		.19b
No lime 8-0-0 (1.5)	.21	.21	.16	.22	.20	.23	.14	.14	.17	.21	.22	.15	.20	.18	.19	
Lime 8-0-0 (1.5)	.22	.22	.17	.22	.21	.22	.14	.15	.17	.19	.21	.15	.20	.17	.19	
Avg.	.22	.22	.17	.22	.21	.23	.14	.15	.17	.20	.22	.15	.20	.18		.19b
No lime 8-0-0 (2)	.21	.23	.17	.22	.21	.23	.14	.14	.16	.22	.21	.14	.19	.17	.19	
Lime 8-0-0 (2)	.19	.23	.17	.21	.21	.23	.14	.14	.16	.19	.23	.15	.19	.17	.19	
Avg.	.20	.23	.17	.22	.21	.23	.14	.14	.16	.21	.22	.15	.19	.17		.19b
No lime 8-12-0 (1)	.20	.22	.17	.22	.20	.25	.13	.13	.17	.22	.22	.16	.20	.19	.19	
Lime 8-12-0 (1)	.20	.23	.16	.23	.21	.25	.14	.15	.16	.23	.23	.15	.21	.19	.20	
Avg.	.20	.23	.17	.23	.21	.25	.14	.14	.17	.23	.23	.16	.21	.19		.20a
No lime 8-12-0 (1.5)	.21	.24	.17	.22	.20	.24	.14	.14	.18	.21	.23	.15	.21	.18	.19	
Lime 8-12-0 (1.5)	.22	.22	.16	.23	.20	.24	.13	.13	.19	.20	.22	.16	.20	.19	.19	
Avg.	.22	.23	.17	.23	.20	.24	.14	.14	.19	.21	.23	.16	.21	.19		19b
No lime 8-12-0 (2)	.21	.22	.17	.22	.20	.23	.14	.15	.16	.22	.23	.15	.21	.19	.19	
Lime 8-12-0 (2)	.21	.22	.16	.21	.22	.24	.14	.14	.19	.23	.25	.15	.21	.20	.20	
Avg.	.21	.22	.17	.22	.21	.24	.14	.15	.18	.23	.24	.15	.21	.20		.20a
No lime 8-12-8 (1)	.21	.23	.17	.24	.20	.23	.14	.14	.17	.22	.22	.16	.20	.19	.19	
Lime 8-12-8 (1)	.21	.21	.16	.22	.20	.24	.13	.15	.18	.21	.23	.16	.20	.20	.19	
Avg.	.21	.22	.17	.23	.20	.24	.14	.15	.18	.22	.23	.16	.20	.20		.19b

(Continued)

Table 8.—(Continued)

Soil amendment and fertilizer[1]	P concentration (% dry wt.)															
	1965	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	$\overline{X}$	Avg.[2]
No lime 8-12-8 (1.5)	.21	.23	.17	.22	.21	.23	.13	.13	.18	.21	.23	.16	.20	.16	.19	
Lime 8-12-8 (1.5)	.19	.22	.16	.22	.21	.24	.14	.15	.19	.21	.23	.16	.21	.20	.20	
Avg.	.20	.23	.17	.22	.21	.24	.14	.14	.19	.21	.23	.16	.21	.18		.20a
Na lime 8-12-8 (2)	.21	.23	.17	.22	.20	.23	.14	.14	.19	.22	.24	.17	.20	.19	.20	
Lime 8-12-8 (2)	.21	.23	.16	.22	.20	.23	.13	.15	.19	.22	.22	.16	.20	.19	.19	
Avg.	.21	.23	.17	.22	.20	.23	.14	.15	.19	.22	.23	.17	.20	.19		.20a
Seasan avg.—no lime[2]	.21	.23	.17	.23	.20	.24	.14	.14	.17	.22	.23	.16	.20	.18	.19a	
Season avg.—lime[2]	.21	.22	.16	.22	.21	.24	.14	.15	.18	.21	.23	.16	.20	.19	.19a	
Seasan avg.	.21	.23	.17	.23	.21	.24	.14	.15	.18	.22	.23	.16	.20	.19		.19

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[1] Applied broadcast under the tips of the branches in February and disked lightly into the soil. Each tree alsa received .04 lb. af N per year of age in July.

[2] Averages followed by different letters are different at the .01 level of probability.

[3] Soil pH maintained at about 6.0 ta 6.5. Same plats received sulphur applications broadcast evenly over the entire plat.

[4] Limed to the extent necessary to maintain soil pH above 6.5 and/or extractable calcium above 3,200 ppm.

[5] Numbers in parentheses denote pounds af fertilizer applied per tree per year of age.

Table 9.—Effect of soil amendment and fertilizer applications on the potassium concentration in the leaves of Washington navel oranges

Soil amendment and fertilizer[1]	K concentration (% dry wt.)															
	1965	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	$\overline{X}$	Avg.[2]
No lime[3] 0-0-0	1.9	2.2	2.1	2.4	2.5	2.3	1.3	2.9	1.4	1.6	1.3	1.6	1.8	1.3	1.9	
Lime[4] 0-0-0	1.8	2.1	2.0	2.1	2.7	2.2	1.4	2.6	1.4	1.5	1.2	1.4	1.9	1.5	2.0	
Avg.	1.9	2.2	2.1	2.3	2.6	2.3	1.4	2.8	1.4	1.6	1.3	1.5	1.9	1.4		1.86a
No lime 8-0-0 (1)[5]	1.9	2.0	1.8	1.9	2.5	1.9	1.2	2.6	1.0	1.4	1.2	1.3	1.6	1.2	1.7	
Lime 8-0-0 (1)	1.8	2.1	2.0	1.9	2.6	2.1	1.2	2.6	1.3	1.5	1.2	1.3	1.7	1.3	1.8	
Avg.	1.9	2.1	1.9	1.9	2.6	2.0	1.2	2.6	1.2	1.5	1.2	1.3	1.7	1.3		1.72bc
No lime 8-0-0 (1.5)	1.9	2.1	2.0	2.0	2.6	2.1	1.1	2.2	1.2	1.5	1.1	1.2	1.5	1.0	1.7	
Lime 8-0-0 (1.5)	2.0	2.0	2.0	1.8	2.5	1.6	1.2	2.5	1.1	1.0	1.0	1.2	1.6	1.1	1.6	
Avg.	2.0	2.1	2.0	1.9	2.6	1.9	1.2	2.4	1.2	1.3	1.1	1.2	1.6	1.1		1.64cd
No lime 8-0-0 (2)	2.1	1.9	1.9	1.8	2.5	1.8	1.1	2.2	1.0	1.4	1.0	1.1	1.6	1.0	1.6	
Lime 8-0-0 (2)	1.8	2.1	2.0	2.0	2.4	1.9	1.2	2.1	1.1	1.3	1.1	1.2	1.5	1.0	1.6	
Avg.	2.0	2.0	2.0	1.9	2.5	1.9	1.2	2.2	1.1	1.4	1.1	1.2	1.6	1.0		1.60e
No lime 8-12-0 (1)	1.9	2.0	2.1	2.1	2.4	2.0	1.2	2.4	1.2	1.4	1.1	1.3	1.5	1.0	1.7	
Lime 8-12-0 (1)	1.8	2.0	1.9	2.1	2.5	1.9	1.2	2.3	1.2	1.5	1.1	1.1	1.7	1.2	1.7	
Avg.	1.9	2.0	2.0	2.1	2.5	2.0	1.2	2.4	1.2	1.5	1.1	1.2	1.6	1.1		1.67cd
No lime 8-12-0 (1.5)	1.9	1.9	2.2	2.0	2.3	2.0	1.2	2.4	1.3	1.5	1.2	1.3	1.6	1.1	1.7	
Lime 8-12-0 (1.5)	2.0	2.1	2.1	1.6	2.4	1.9	1.2	2.4	1.2	1.4	1.1	1.3	1.7	1.2	1.7	
Avg.	2.0	2.0	2.2	1.8	2.4	2.0	1.2	2.4	1.3	1.5	1.2	1.3	1.7	1.2		1.69bcd
No lime 8-12-0 (2)	1.9	2.1	2.1	1.8	2.3	1.9	1.2	2.3	1.1	1.4	1.1	1.2	1.4	1.0	1.6	
Lime 8-12-0 (2)	1.8	2.1	2.0	1.8	2.6	1.9	1.1	2.1	1.2	1.3	1.1	1.0	1.6	1.2	1.6	
Avg.	1.9	2.1	2.1	1.8	2.5	1.9	1.2	2.2	1.2	1.4	1.1	1.1	1.5	1.1		1.62d
No lime 8-12-8 (1)	1.9	1.8	1.9	2.1	2.6	2.1	1.3	2.4	1.1	1.6	1.3	1.4	1.8	1.5	1.8	
Lime 8-12-8 (1)	1.9	1.9	1.9	2.1	2.5	2.0	1.3	2.5	1.5	1.7	1.4	1.4	1.9	1.5	1.8	
Avg.	1.9	1.9	1.9	2.1	2.6	2.1	1.3	2.5	1.3	1.7	1.4	1.4	1.9	1.5		1.78ab

(Continued)

Table 9 (Continued)

Soil amendment and fertilizer[1]	K concentration (% dry wt.)															
	1965	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	$\bar{X}$	Avg.[2]
No lime 8-12-8 (1.5)	1.9	2.0	2.0	1.9	2.6	1.9	1.1	2.1	1.3	1.5	1.2	1.3	1.7	1.3	1.7	
Lime 8-12-8 (1.5)	1.8	2.1	2.0	1.9	2.7	1.9	1.2	2.1	1.5	1.4	1.1	1.4	1.8	1.3	1.7	
Avg.	1.9	2.1	2.0	1.9	2.7	1.9	1.2	2.1	1.4	1.5	1.2	1.4	1.8	1.3		1.71bcd
No lime 8-12-8 (2)	2.0	2.0	2.0	1.9	2.5	1.8	1.1	2.1	1.4	1.6	1.3	1.4	1.9	1.4	1.7	
Lime 8-12-8 (2)	1.9	1.9	2.0	1.9	2.5	1.8	1.2	2.4	1.2	1.5	1.2	1.4	1.8	1.3	1.7	
Avg.	2.0	2.0	2.0	1.9	2.5	1.8	1.2	2.3	1.3	1.6	1.3	1.4	1.9	1.4		1.72bc
Season avg.—no lime[2]	1.9	2.0	2.0	2.0	2.5	2.0	1.2	2.4	1.2	1.5	1.2	1.3	1.6	1.2	1.70a	
Season avg.—lime[2]	1.9	2.0	2.0	1.9	2.5	1.9	1.2	2.4	1.3	1.4	1.2	1.3	1.7	1.3	1.70a	
Season avg.	1.9	2.0	2.0	2.0	2.5	2.0	1.2	2.4	1.3	1.5	1.2	1.3	1.7	1.3		1.70

[1] Applied broadcast under the tips of the branches in February and disked lightly into the soil. Each tree also received .04 lb. of N per year of age in July.

[2] Averages followed by different letters are different at the .01 level of probability.

[3] Soil pH maintained at about 6.0 to 6.5. Some plots received sulphur applications broadcast evenly over the entire plot.

[4] Limed to the extent necessary to maintain soil pH above 6.5 and/or extractable calcium above 3,200 ppm.

[5] Numbers in parentheses denote pounds of fertilizer applied per tree per year of age.

Table 10.—Effects of soil amendment and fertilizer applications on the calcium concentration in the leaves of Washington navel oranges

Soil amendment and fertilizer[1]	Ca concentration (% dry wt.)														
	1965	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	$\bar{X}$	Avg.[2]
No lime[3] 0-0-0	3.6	2.7	3.0	2.8	2.5	3.0	3.9	4.8	4.0	2.6	3.7	3.6	2.1	3.3	3.3	
Lime[4] 0-0-0	3.3	2.6	2.9	3.1	1.7	3.2	3.9	4.7	4.2	2.8	3.6	4.0	1.9	3.4	3.2	
Avg.	3.5	2.7	3.0	3.0	2.1	3.1	3.9	4.8	4.1	2.7	3.7	3.8	2.0	3.4		3.23c
No lime 8-0-0 (1)[5]	3.1	2.8	2.8	3.3	2.0	3.3	4.3	4.8	4.6	2.8	3.9	3.9	2.1	4.0	3.4	
Lime 8-0-0 (1)	3.3	3.0	2.9	3.3	1.9	3.0	4.2	5.4	4.2	2.8	4.0	3.7	2.1	4.1	3.4	
Avg.	3.2	2.9	2.9	3.3	2.0	3.2	4.3	5.1	4.4	2.8	4.0	3.8	2.1	4.1		3.41a
No lime 8-0-0 (1.5)	3.4	2.6	2.7	3.1	1.9	3.0	4.4	5.0	4.5	3.0	4.1	3.8	2.2	3.4	3.4	
Lime 8-0-0 (1.5)	3.2	2.7	2.8	3.1	1.7	3.2	4.3	4.7	4.5	3.2	4.2	4.1	2.0	4.0	3.4	
Avg.	3.3	2.7	2.8	3.1	1.8	3.1	4.4	4.9	4.5	3.1	4.2	4.0	2.1	3.7		3.38ab
No lime 8-0-0 (2)	3.2	2.6	2.9	3.1	1.8	3.1	4.1	4.4	4.7	2.8	4.0	4.0	2.1	3.9	3.3	
Lime 8-0-0 (2)	3.2	3.0	2.8	3.0	1.8	3.0	4.1	4.5	4.1	3.2	3.9	4.0	2.1	4.1	3.3	
Avg.	3.2	2.8	2.9	3.1	1.8	3.1	4.1	4.5	4.4	3.0	4.0	4.0	2.1	4.0		3.34abc
No lime 8-12-0 (1)	3.1	2.7	2.9	3.2	2.6	3.0	4.1	4.9	4.2	2.6	3.6	3.8	2.0	4.0	3.3	
Lime 8-12-0 (1)	3.3	2.7	2.9	3.2	1.9	3.1	4.3	5.0	4.6	2.7	3.9	3.9	2.0	3.6	3.4	
Avg.	3.2	2.7	2.9	3.2	2.3	3.1	4.2	5.0	4.4	2.7	3.8	3.9	2.0	3.8		3.34abc
No lime 8-12-0 (1.5)	3.2	2.7	2.7	3.2	2.7	2.9	4.1	4.7	3.8	2.8	3.5	3.7	2.0	3.6	3.3	
Lime 8-12-0 (1.5)	3.2	2.7	2.9	3.4	1.9	3.3	4.2	4.9	4.2	3.0	4.0	3.9	2.0	4.1	3.4	
Avg.	3.2	2.7	2.8	3.3	2.3	3.1	4.2	4.8	4.0	2.9	3.8	3.8	2.0	3.9		3.33abc
No lime 8-12-0 (2)	3.2	2.7	2.7	3.1	2.4	3.1	4.1	4.7	4.2	2.5	3.6	3.8	2.1	3.6	3.3	
Line 8-12-0 (2)	3.1	2.7	2.8	3.5	1.8	3.1	4.2	5.2	4.1	2.7	3.9	4.1	2.0	3.8	3.4	
Avg.	3.2	2.7	2.8	3.3	2.1	3.1	4.2	5.0	4.2	2.6	3.8	4.0	2.1	3.7		3.10abc
No lime 8-12-8 (1)	3.3	2.9	2.7	3.1	1.8	3.1	4.0	4.8	4.0	2.5	3.5	3.8	2.0	3.2	3.2	
Lime 8-12-8 (1)	3.3	2.8	2.9	3.2	2.0	3.0	4.2	4.8	4.3	2.5	4.0	3.8	2.0	3.7	3.3	
Avg.	3.3	2.9	2.8	3.2	1.9	3.1	4.1	4.8	4.2	2.5	3.8	3.8	2.0	3.5		3.25c

(Continued)

Table 10.—(Continued)

	Ca concentration (% dry wt.)															
Soil amendment and fertilizer[1]	1965	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	$\overline{X}$	Avg.[2]
No lime 8-12-8 (1.5)	3.2	2.5	2.8	3.0	1.8	3.2	4.2	4.8	4.0	2.8	3.7	3.6	2.1	3.6	3.2	
Lime 8-12-8 (1.5)	3.4	2.8	2.8	3.3	1.8	3.5	4.1	5.2	3.9	2.7	3.9	3.6	1.9	3.7	3.3	
Avg.	3.3	2.7	2.8	3.2	1.8	3.4	4.2	5.0	4.0	2.8	3.8	3.6	2.0	3.7		3.28bc
No lime 8-12-8 (2)	3.5	2.8	2.9	3.2	1.8	3.1	4.2	4.9	4.0	2.5	3.3	3.7	2.0	3.6	3.3	
Lime 8-12-8 (2)	3.2	2.9	3.0	3.2	2.1	3.3	4.3	5.0	4.0	2.9	3.8	3.7	1.9	3.9	3.4	
Avg.	3.4	2.9	3.0	3.2	2.0	3.2	4.3	5.0	4.0	2.7	3.6	3.7	2.0	3.8		3.31abc
Season avg.—no lime[2]	3.3	2.7	2.8	3.1	2.1	3.1	4.1	4.8	4.2	2.7	3.7	3.8	2.1	3.6	3.28a	
Season avg.—lime[2]	3.3	2.8	2.9	3.2	1.9	3.2	4.2	4.9	4.2	2.9	3.9	3.9	2.0	3.8	3.35a	
Season avg.	3.3	2.8	2.9	3.2	2.0	3.2	4.2	4.9	4.2	2.8	3.8	3.9	2.1	3.7		3.30

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[1] Applied broadcast under the tips of the branches in February and disked lightly into the soil. Each tree also received .04 lb. of N per year of age in July.

[2] Averages followed by different letters are different at the .01 level of probability.

[3] Soil pH maintained at about 6.0 to 6.5. Some plots received sulphur applications broadcast evenly over the entire plot.

[4] Limed to the extent necessary to maintain soil pH above 6.5 and/or extractable calcium above 3,200 ppm.

[5] Numbers in parentheses denote pounds of fertilizer applied per tree per year of age.

Table 11.—Effects of soil amendment and fertilizer application on the magnesium concentration in the leaves of Washington navel oranges

Soil amendment and fertilizer[1]	Mg concentration (% dry wt.)														
	1965	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	$\bar{X}$	Avg.[2]
No lime[3] 0-0-0	.31	.31	.30	.37	.38	.37	.29	.37	.37	.34	.33	.37	.38	.41	.35	
Lime[4] 0-0-0	.37	.33	.34	.41	.41	.37	.29	.40	.38	.36	.34	.37	.35	.36	.36	
Avg.	.34	.32	.32	.39	.40	.37	.29	.39	.38	.35	.34	.37	.37	.39		.36a
No lime 8-0-0 (1)[5]	.36	.33	.32	.42	.40	.40	.33	.40	.33	.38	.40	.40	.36	.42	.38	
Lime 8-0-0 (1)	.35	.32	.31	.41	.38	.37	.28	.38	.34	.34	.41	.39	.39	.47	.37	
Avg.	.36	.33	.32	.42	.39	.39	.31	.39	.34	.36	.41	.40	.38	.45		.38a
No lime 8-0-0 (1.5)	.35	.31	.32	.44	.38	.38	.29	.41	.36	.38	.42	.39	.40	.45	.38	
Lime 8-0-0 (1.5)	.32	.34	.33	.40	.40	.37	.28	.39	.37	.36	.43	.40	.36	.44	.37	
Avg.	.34	.33	.33	.42	.39	.38	.29	.40	.37	.37	.43	.40	.38	.45		.38a
No lime 8-0-0 (2)	.36	.33	.32	.42	.40	.41	.33	.41	.39	.38	.45	.41	.35	.41	.38	
Lime 8-0-0 (2)	.35	.34	.33	.38	.41	.38	.30	.38	.35	.34	.40	.38	.40	.49	.37	
Avg.	.36	.34	.33	.40	.41	.40	.32	.40	.37	.36	.43	.40	.48	.45		.38a
No lime 8-12-0 (1)	.35	.34	.30	.43	.41	.38	.30	.39	.36	.36	.46	.41	.39	.48	.38	
Lime 8-12-0 (1)	.34	.32	.32	.41	.41	.38	.29	.43	.38	.36	.47	.41	.37	.46	.38	
Avg.	.35	.33	.31	.42	.41	.38	.30	.41	.37	.36	.47	.41	.38	.47		.38a
No lime 8-12-0 (1.5)	.34	.35	.31	.44	.42	.37	.32	.46	.38	.36	.47	.39	.36	.43	.39	
Lime 8-12-0 (1.5)	.34	.32	.33	.40	.40	.37	.30	.35	.36	.35	.40	.39	.36	.47	.37	
Avg.	.34	.34	.32	.42	.41	.37	.31	.41	.37	.36	.44	.39	.36	.46		38a
No lime 8-12-0 (2)	.36	.34	.30	.44	.41	.42	.34	.44	.40	.35	.47	.43	.36	.45	.39	
Lime 8-12-0 (2)	.36	.32	.33	.41	.39	.38	.31	.41	.37	.34	.44	.38	.39	.49	.38	
Avg.	.36	.31	.32	.43	.40	.40	.33	.43	.39	.35	.46	.41	.38	.47		.39a
No lime 8-12-8 (1)	.37	.34	.32	.42	.41	.38	.32	.41	.36	.36	.43	.40	.35	.38	.38	
Lime 8-12-8 (1)	.37	.32	.33	.38	.39	.38	.28	.41	.35	.33	.43	.36	.35	.42	.36	
Avg.	.37	.33	.33	.40	.40	.38	.30	.41	.36	.35	.43	.38	.35	.40		.37a

(Continued)

Table 11.—(Continued)

Soil amendment and fertilizer[1]	Mg concentration (% dry wt.)														
	1965	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	$\bar{X}$	Avg.[2]
No lime 8-12-8 (1.5)	.37	.34	.34	.41	.41	.42	.34	.42	.39	.37	.45	.41	.36	.41	.39	
Lime 8-12-8 (1.5)	.39	.32	.31	.40	.39	.37	.30	.35	.34	.36	.43	.39	.38	.44	.37	
Avg.	.38	.33	.33	.41	.40	.40	.32	.39	.37	.37	.44	.40	.37	.43		.38a
No lime 8-12-8 (2)	.36	.33	.31	.42	.38	.40	.31	.41	.35	.36	.43	.39	.36	.39	.37	
Lime 8-12-8 (2)	.36	.32	.32	.41	.39	.38	.35	.34	.35	.34	.43	.35	.35	.43	.37	
Avg.	.36	.33	.32	.41	.39	.39	.33	.38	.35	.35	.43	.37	.36	.41		.37a
Season avg.—no lime[2]	.35	.33	.31	.42	.40	.39	.32	.41	.37	.36	.43	.40	.37	.42	.37a	
Season avg.—lime[2]	.36	.33	.33	.40	.40	.38	.30	.38	.36	.35	.42	.38	.37	.45	.37a	
Season avg.	.36	.33	.32	.41	.40	.39	.31	.40	.37	.36	.43	.39	.37	.44		.37

[1] Applied broadcast under the tips of the branches in February and disked lightly into the soil. Each tree also received .04 lb. of N per year of age in July.

[2] Averages followed by the same letter are not different at the .05 level of probability.

[3] Soil pH maintained at about 6.0 to 6.5. Same plots received sulphur applications broadcast evenly over the entire plot.

[4] Limed to the extent necessary to maintain soil pH above 6.5 and/or extractable calcium above 3,200 ppm.

[5] Numbers in parentheses denote pounds of fertilizer applied per tree per year of age.

Table 12.—Effects of soil amendment and fertilizer applications on the manganese concentration in the leaves of Washington navel oranges

Soil amendment and fertilizer[1]	Mn concentration (ppm—dry tissue)															
	1965	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	$\bar{X}$	Avg.[2]
No lime[3] 0-0-0	10	22	15	—*	—*	10	21	21	22	17	23	31	16	13	18	
Lime[4] 0-0-0	6	24	16	—	—	6	16	17	23	14	17	17	28	24	17	
Avg.	8	21	16	—	—	8	19	19	23	16	20	24	21	18		18g
No lime 8-0-0 (1)[5]	11	19	14	—	—	11	25	26	34	23	28	45	18	19	23	
Lime 8-0-0 (1)	9	22	17	—	—	9	20	21	22	18	21	22	27	32	20	
Avg.	10	21	16	—	—	10	23	24	28	21	25	34	23	26		23ef
No lime 8-0-0 (1.5)	12	20	15	—	—	12	21	33	26	21	28	32	23	25	22	
Lime 8-0-0 (1.5)	10	23	16	—	—	10	16	21	25	25	29	29	25	29	22	
Avg.	11	22	16	—	—	11	19	27	26	23	29	31	24	27		23ef
No lime 8-0-0 (2)	16	25	14	—	—	16	30	36	35	27	33	45	26	27	28	
Lime 8-0-0 (2)	12	22	15	—	—	12	24	29	27	26	27	35	32	35	25	
Avg.	14	24	15	—	—	14	27	33	31	27	30	40	29	31		27bcde
No lime 8-12-0 (1)	14	21	18	—	—	14	27	31	27	23	31	44	26	27	25	
Lime 8-12-0 (1)	11	24	13	—	—	11	15	19	25	20	34	44	27	29	23	
Avg.	13	23	16	—	—	13	21	25	26	22	33	44	27	28		25cdef
No lime 8-12-0 (1.5)	17	24	15	—	—	17	34	43	29	24	33	42	34	33	29	
Lime 8-12-0 (1.5)	11	24	15	—	—	11	19	25	25	28	32	37	32	30	24	
Avg.	14	24	15	—	—	14	27	34	27	26	33	40	33	32		28bcd
No lime 8-12-0 (2)	18	23	14	—	—	16	38	48	40	26	40	51	28	36	32	
Lime 8-12-0 (2)	12	23	15	—	—	12	20	27	27	24	27	37	33	35	24	
Avg.	15	23	15	—	—	14	29	38	34	25	34	44	31	36		30bc
No lime 8-12-8 (1)	15	23	14	—	—	15	29	27	35	26	35	49	22	19	26	
Lime 8-12-8 (1)	12	22	15	—	—	12	18	23	24	18	25	28	33	35	22	
Avg.	14	23	15	—	—	14	24	26	30	22	30	39	28	27		25def

(Continued)

Table 12.—(Continued)

Soil amendment and fertilizer[1]	Mn concentration (ppm—dry tissue) 1965	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	$\bar{X}$	Avg.[2]
No lime 8-12-8 (1.5)	20	22	14	—	—	18	40	44	34	24	37	51	32	29	26	
Lime 8-12-8 (1.5)	12	23	16	—	—	12	22	27	28	27	32	45	33	33	26	
Avg.	16	23	15	—	—	15	31	36	31	26	35	48	33	31		30b
No lime 8-12-8 (2)	22	23	15	—	—	19	46	60	42	29	43	55	23	41	35	
Lime 8-12-8 (2)	15	23	14	—	—	15	27	33	29	30	35	39	40	45	29	
Avg.	19	23	15	—	—	17	37	47	36	30	39	47	32	43		34a
Season avg.—no lime[2]	16	22	15	—	—	15	31	37	32	24	33	45	25	27	27a	
Season avg.—lime[2]	11	23	15	—	—	11	20	24	26	23	28	33	31	33	23b	
Season avg.	14	23	15	—	—	13	26	31	29	24	31	39	28	30		25

[1] Applied broadcast under the tips of the branches in February and disked lightly into the soil. Each tree also received .04 lb. of N per year of age in July.

[2] Averages followed by different letters are different at the .01 level of probability.

[3] Soil pH maintained at about 6.0 to 6.5. Some plots received sulphur applications broadcast evenly over the entire plot.

[4] Limed to the extent necessary to maintain soil pH above 6.5 and/or extractable calcium above 3,200 ppm.

[5] Numbers in parentheses denote pounds of fertilizer applied per tree per year of age.

*Data not available for 1969 and 1970.

Table 13.—Effects of soil amendments and fertilizer applications on the zinc concentration in the leaves of Washington navel oranges

Soil amendment and fertilizer[1]	Zn concentration (ppm—dry tissue)															
	1965	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	$\bar{X}$	Avg.[2]
No lime[3] 0-0-0	15	16	16	—*	—*	16	24	17	16	13	20	44	15	22	20	
Lime[4] 0-0-0	14	23	10	—	—	14	22	17	13	14	10	37	18	29	18	
Avg.	15	20	13	—	—	15	23	17	15	14	15	41	17	25		19a
No lime 8-0-0 (1)[5]	14	19	17	—	—	14	21	21	12	22	14	40	15	29	20	
Lime 8-0-0 (1)	20	20	19	—	—	20	22	18	16	16	12	42	16	29	21	
Avg.	17	20	18	—	—	17	22	20	14	19	13	41	16	29		21a
No lime 8-0-0 (1.5)	15	19	32	—	—	15	25	18	14	13	16	37	17	31	21	
Lime 8-0-0 (1.5)	27	20	16	—	—	27	19	18	16	13	13	42	16	37	22	
Avg.	21	20	24	—	—	21	22	18	15	13	15	40	17	34		22a
No lime 8-0-0 (2)	16	19	18	—	—	16	19	18	16	14	13	41	15	24	19	
Lime 8-0-0 (2)	17	22	19	—	—	17	19	17	15	13	13	39	15	25	19	
Avg.	17	21	19	—	—	17	19	18	16	14	13	40	15	25		19a
No lime 8-12-0 (1)	15	19	17	—	—	16	21	19	15	12	13	45	14	21	19	
Lime 8-12-0 (1)	14	19	16	—	—	14	21	17	18	13	12	41	15	24	19	
Avg.	15	19	17	—	—	15	21	18	17	13	13	43	15	23		19a
No lime 8-12-0 (1.5)	13	19	21	—	—	13	19	17	17	12	15	44	14	31	20	
Lime 8-12-0 (1.5)	14	17	18	—	—	14	19	16	18	16	12	36	17	30	19	
Avg.	14	18	20	—	—	14	19	17	18	14	14	40	16	31		20a
No lime 8-12-0 (2)	21	20	20	—	—	19	19	15	15	12	12	40	13	21	19	
Lime 8-12-0 (2)	13	20	18	—	—	13	23	16	15	12	11	41	13	23	18	
Avg.	17	20	19	—	—	16	21	16	15	12	12	41	13	22		19a
No lime 8-12-8 (1)	16	20	19	—	—	16	22	18	13	12	14	43	13	30	20	
Lime 8-12-8 (1)	20	21	17	—	—	20	21	19	20	14	11	39	18	30	21	
Avg.	18	21	18	—	—	18	22	19	17	13	13	41	16	30		21a

(Continued)

Table 13.—(Continued)

Soil amendment ond fertilizer[1]	Zn concentration (ppm—dry tissue)														
	1965	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	$\bar{X}$	Avg.[2]
Na lime 8-12-8 (1.5)	15	18	21	—	—	15	21	16	15	13	15	38	14	22	19	
Lime 8-12-8 (1.5)	17	20	18	—	—	17	20	17	19	13	10	36	16	29	19	
Avg.	16	19	20	—	—	16	21	17	17	13	13	37	15	25		19o
Na lime 8-12-8 (2)	14	20	23	—	—	13	21	19	17	14	16	37	14	21	19a	
Lime 8-12-8 (2)	15	19	18	—	—	15	19	18	17	14	11	41	14	29	19a	
Avg.	15	20	21	—	—	14	20	19	17	14	14	39	14	25		19
Season ovg.—no lime[2]	15	19	20	—	—	15	21	18	15	14	15	41	14	25		19
Seoson avg.—lime[2]	17	20	17	—	—	17	21	17	17	14	12	39	16	29		20
Seoson ovg.	16	20	19	—	—	16	21	18	16	14	14	40	15	27		20

[1] Applied braadcast under the tips af the branches in February and disked lightly inta the soil. Each tree olso received .04 lb. of N per year af age in July.

[2] Averages followed by the same letter are not different at the .05 level af probobility.

[3] Soil pH mointained at about 6.0 ta 6.5. Some plots received sulphur opplications broadcast evenly over the entire plat.

[4] Limed ta the extent necessary to mointain soil pH abave 6.5 and/ar extroctable calcium obove 3,200 ppm.

[5] Numbers in parentheses denote pounds of fertilizer opplied per tree per year of age.

*Data nat avoilable far 1969 and 1970.

deficiency symptoms appear. Since several samples in this study were found to contain less than 15 ppm of Zn, it was not surprising to observe symptoms of shortage in the leaves from some of these plots (Tables 13 and 16). (Zinc analyses were not run in 1969 or 1970.)

On several occasions during the study a partial chlorosis of the foliage occurred. The symptoms were typical of an abnormally low concentration of manganese in the leaves, and the condition was classified as manganese deficiency. During two seasons, 1967 and 1971, when these symptoms appeared on the leaves the severity of the chlorosis was determined subjectively by plot (Tables 14 and 15).

In 1967, the season when manganese deficiency was very noticeable, all trees showed some degree of shortage; however, trees receiving complete fertilizer at the heaviest rate and no lime showed the fewest symptoms. Symptoms were also light on trees fertilized at the medium rate with complete fertilizer, with the most pronounced symptoms appearing on trees receiving only nitrogen or no fertilizer. The effect of lime use on the severity of the symptoms was erratic, thus masking any possible relationship between these two factors. In this situation, the limed plots might be expected to show the most severe symptoms; however, these trees were still quite young, and the differences in soil reaction among plots were not very great.

Table 14.—Effects of fertilizer and lime treatments on the incidence of interveinal chlorosis in the foliage of Washington navel orange trees, August 1967

Fertilizer treatment[1]	Lime treatment		Fertilizer average
	None[2]	Lime[3]	
	Chlorosis rating[4]		
0-0-0	6.25	5.50	5.88
8-0-0 (1)[5]	6.50	5.00	5.75
8-0-0 (1.5)	6.75	6.25	6.50
8-0-0 (2)	6.25	5.50	5.88
8-12-0 (1)	6.00	6.75	6.38
8-12-0 (1.5)	5.25	6.50	5.88
8-12-0 (2)	4.75	5.50	5.13
8-12-8 (1)	6.25	7.50	6.88
8-12-8 (1.5)	5.00	4.50	4.75
8-12-8 (2)	3.50	5.00	4.25
Lime average	5.65	5.80	

For comparing fertilizer averages, H.S.D. @ .05 = 2.30

F value for lime treatment effects—ns (.05).

F value for interaction of fertilizer x lime—ns (.05).

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[1] Applied broadcast under the tips of the branches in February and disked lightly into the soil. Each tree also received .04 lb. of N per year of age broadcast under the branches in July as ammonium nitrate.

[2] Soil pH maintained at about 6.0 to 6.5.

[3] Soil pH maintained above 6.5.

[4] Based on a scale of 0 = no chlorosis to 10 = severe chlorosis on the leaves of the second flush of growth (manganese deficiency).

[5] Numbers in parentheses denote pounds of fertilizer applied per tree per year of age.

In the 1971 season, when the symptoms of manganese deficiency were relatively mild, fewer symptoms were shown again by trees treated with either the medium or heavy rate of complete fertilizer. The unfertilized trees clearly exhibited the most marked deficiency, and those receiving only nitrogen were intermediate in symptom severity. During this season a definite pattern was established in which the limed plots produced more pronounced symptoms than the unlimed ones in every case. Evidently the differences in soil reaction had been more definitely established and the trees at this age varied in their capacity to absorb sufficient amounts of manganese from the soil to meet their needs.

A second abnormality of the foliage also appeared during the 1971 season. It was diagnosed as zinc deficiency. The severity of the symptoms was determined subjectively (Table 16). Symptoms were more striking in the unfertilized trees than in those receiving any type of fertilization. No real difference could be found in the severity of these symptoms due to the kind or rate of fertilization used. Neither was there any evidence that liming the soil affected the severity of the symptoms. Again, it might be expected that use of lime in sufficient quantities to cause major differences in the soil reaction would affect the relative efficiency of zinc absorption from the soil by the trees, but in this study the rate of lime application was only heavy enough to cause small changes in the soil reaction.

Table 15.—Effects of fertilizer and lime treatments on the incidence of manganese deficiency symptoms of Washington navel orange trees, September 1971

Fertilizer treatment[1]	Lime treatment		Fertilizer average
	None[2]	Lime[3]	
	Mn deficiency symptoms[4]		
0-0-0	2.7	3.1	2.9
8-0-0 (1)[5]	1.1	1.9	1.5
8-0-0 (1.5)	1.1	1.7	1.4
8-0-0 (2)	0.5	1.7	1.1
8-12-0 (1)	0.9	1.8	1.3
8-12-0 (1.5)	0.6	0.8	0.7
8-12-0 (2)	0.3	0.9	0.6
8-12-8 (1)	0.1	1.4	0.8
8-12-8 (1.5)	0.2	0.5	0.4
8-12-8 (2)	0.2	1.4	0.8
Lime average	0.8	1.5	

For comparing fertilizer averages, H.S.D. @ .05 = 1.0.
For comparing lime averages, H.S.D. @ .01 = 0.5.
F value for fertilizer x lime interaction—ns (0.05).

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[1] Applied broadcast under the tips of the branches in February and disked lightly into the soil. Each tree also received .04 lb. of N per year of age broadcast under the branches in July as ammonium nitrate.

[2] Soil pH maintained at about 6.0 to 6.5.

[3] Soil pH maintained above 6.5.

[4] Based on a scale of 0 = no leaves showing manganese deficiency symptoms to 4 = more than 75 percent of the leaves on the last flush of growth showing symptoms.

[5] Numbers in parentheses denote pounds of fertilizer applied per tree per year of age.

Table 16.—Effects of fertilizer and lime treatments on the incidence of zinc deficiency symptoms of Washington navel orange trees, September 1971

Fertilizer treatment[1]	Lime treatment: None[2]	Lime treatment: Lime[3]	Fertilizer average
	Zn deficiency symptoms[4]		
0-0-0	0.9	1.1	1.00
8-0-0 (1)[5]	0.2	0.1	0.15
8-0-0 (1.5)	0.2	0.6	0.40
8-0-0 (2)	0.2	0.4	0.30
8-12-0 (1)	0.2	0.0	0.10
8-12-0 (1.5)	0.4	0.3	0.35
8-12-0 (2)	0.2	0.2	0.20
8-12-8 (1)	0.0	0.1	0.05
8-12-8 (1.5)	0.1	0.0	0.05
8-12-8 (2)	0.2	0.5	0.35
Lime average	0.3	0.3	

For comparing fertilizer averages, H.S.D. @ .01 = 0.79.
F value for lime treatment effects—ns (.05).
F value for fertilizer x lime interaction—ns (.05).

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[1] Applied broadcast under the tips of the branches in February and disked lightly into the soil. Each tree also received .04 lb. of N per year of age broadcast under the branches in July as ammonium nitrate.

[2] Soil pH maintained at about 6.0 to 6.5.

[3] Soil pH maintained above 6.5.

[4] Based on a scale of 0 = no leaves showing zinc deficiency symptoms to 4 = more than 75 percent of the leaves on the last flush of growth showing symptoms.

[5] Numbers in parentheses denote pounds of fertilizer applied per tree per year of age.

The reaction of the soil in each plot at the beginning of the study, along with that of samples taken periodically during the work, is shown in Table 17. There was a gradual decline in soil pH in most plots, even in those receiving lime applications; however, the limed plots were usually higher in pH than the unlimed ones. This is shown by comparison of values within a fertilizer treatment during any season and also by the overall average effect of lime at the last sampling date, whether viewed on a treatment basis or a general basis. A significant interaction occurred between lime and season, inferring that the effect of lime on soil pH was not constant. It should be noted that unfertilized plots tended to decrease less in soil pH than those receiving fertilizer of any type or rate. The heavier rates of fertilization appeared to have the most depressing effect on the soil reaction.

The extractable calcium in the soil was not affected by the type of fertilizer used or even by the lime application during the course of the study (Table 18). The only factor responsible for any variation in the calcium level was season of sampling. There was a general decline in extractable calcium, especially during the later seasons, regardless of the fertilizer or lime treatment used. Within most treatments there appeared to be more calcium available in the limed plots than in the unlimed ones.

Table 17.—Effects of soil amendment and fertilizer applications on the soil reaction (pH), 1965-78

Soil amendment and fertilizer[1]	Soil pH							
	1965	1967	1969	1972	1974	1978	$\bar{X}$	Avg.[2]
No lime[3] 0-0-0	6.8	6.8	6.4	6.4	6.6	6.2	6.5	
Lime[4] 0-0-0	7.2	7.2	6.9	6.8	6.9	6.8	7.0	
Avg.	7.0	7.0	6.7	6.6	6.8	6.5		6.8a
No lime 8-0-0 (1)[5]	6.9	7.0	6.5	6.5	6.4	5.9	6.5	
Lime 8-0-0 (1)	6.7	6.8	6.4	6.7	6.7	6.4	6.6	
Avg.	6.8	6.9	6.5	6.6	6.6	6.2		6.6a
No lime 8-0-0 (1.5)	6.8	6.7	6.3	6.1	6.3	5.4	6.3	
Lime 8-0-0 (1.5)	7.0	7.0	6.7	6.8	6.8	6.1	6.7	
Avg.	6.9	6.9	6.5	6.5	6.6	5.8		6.5a
No lime 8-0-0 (2)	6.9	6.9	6.1	6.2	6.0	5.6	6.3	
Lime 8-0-0 (2)	6.6	6.8	6.2	6.6	6.3	6.2	6.5	
Avg.	6.8	6.9	6.2	6.4	6.2	5.9		6.4a
No lime 8-12-0 (1)	6.8	6.6	6.2	5.9	6.4	5.8	6.3	
Lime 8-12-0 (1)	6.8	7.0	6.7	6.7	6.5	6.1	6.6	
Avg.	6.8	6.8	6.5	6.3	6.4	6.0		6.5a
No lime 8-12-0 (1.5)	6.6	6.3	5.9	6.0	6.0	5.7	6.1	
Lime 8-12-0 (1.5)	6.8	6.8	6.5	6.6	6.8	6.3	6.6	
Avg.	6.7	6.5	5.7	6.3	6.4	6.0		6.4a
No lime 8-12-0 (2)	6.7	6.5	5.9	5.7	6.1	5.5	6.1	
Lime 8-12-0 (2)	6.7	6.9	6.3	6.5	6.6	6.0	6.5	
Avg.	6.7	6.7	6.1	6.1	6.4	5.8		6.3a
No lime 8-12-8 (1)	6.9	6.8	6.3	6.3	6.5	5.8	6.4	
Lime 8-12-8 (1)	6.8	6.8	6.5	6.5	6.7	6.4	6.6	
Avg.	6.9	6.8	6.4	6.4	6.6	6.1		6.5a
No lime 8-12-8 (1.5)	6.7	6.5	5.9	5.9	6.0	5.7	6.1	
Lime 8-12-8 (1.5)	7.2	7.1	6.7	6.5	6.6	6.4	6.8	
Avg.	7.0	6.8	6.2	6.2	6.3	6.1		6.5a
No lime 8-12-8 (2)	6.7	6.6	6.0	5.9	6.1	5.4	6.1	
Lime 8-12-8 (2)	6.9	6.9	6.4	6.5	6.5	6.3	6.6	
Avg.	6.8	6.8	6.2	6.2	6.3	5.9		6.4a
Season avg.—no lime[2]	6.8	6.7	6.2	6.1	6.2	5.7	6.3a	
Season avg.—lime[2]	6.9	6.9	6.5	6.6	6.6	6.3	6.6b	
Season avg.	6.9	6.8	6.4	6.4	6.4	6.0		6.5

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[1] Applied broadcast under the tips of the branches in February and disked lightly into the soil. Each tree also received .04 lb. of N per year of age broadcast under the branches in July as ammonium nitrate.

[2] Averages followed by different letters are different at the .05 level of probability.

[3] Soil pH maintained at about 6.0 to 6.5. Some plots received sulphur applications broadcast evenly over the entire plot.

[4] Limed to the extent necessary to maintain soil pH above 6.5 and/or extractable calcium above 3,200 ppm.

[5] Numbers in parentheses denote pounds of fertilizer applied per tree per year of age.

Table 18.—Effects of soil amendment and fertilizer applications on the amount of extractable calcium in the soil, 1965-78

Soil amendment and fertilizer[1]	Extractable calcium (ppm)							
	1965	1967	1969	1972	1974	1978	$\bar{X}$	Avg.[2]
No lime[3] 0-0-0	3080	3898	2435	4090	2715	2510	3121	
Lime[4] 0-0-0	3235	3223	3293	3260	2638	2695	3057	
Avg.	3158	3561	2864	3675	2676	2603		3089a
Na lime 8-0-0 (1)[5]	3055	2993	2853	3090	2453	2275	2787	
Lime 8-0-0 (1)	3100	3415	3508	3250	2615	2433	3054	
Avg.	3078	3204	3181	3170	2534	2354		2921a
Na lime 8-0-0 (1.5)	3130	3228	3405	3210	2493	2181	2941	
Lime 8-0-0 (1.5)	2923	2825	2725	3140	2625	2325	2761	
Avg.	3027	3027	3065	3175	2559	2253		2851a
No lime 8-0-0 (2)	2983	2958	2750	2900	2260	2140	2665	
Lime 8-0-0 (2)	2818	2733	2798	3150	2553	2525	2763	
Avg.	2901	2846	2774	3025	2407	2333		2714a
Na lime 8-12-0 (1)	2910	3025	2935	2850	2450	2219	2732	
Lime 8-12-0 (1)	3035	3015	3078	3120	2535	2316	2850	
Avg.	2973	3020	3007	2985	2493	2268		2791a
No lime 8-12-0 (1.5)	2943	2880	2848	2960	2428	2273	2722	
Lime 8-12-0 (1.5)	2913	2893	2935	3070	2613	2496	2820	
Avg.	2928	2887	2892	3015	2521	2385		2771a
No lime 8-12-0 (2)	2960	2848	2930	2720	2253	2011	2620	
Lime 8-12-0 (2)	2818	3008	2785	2990	2480	2408	2748	
Avg.	2889	2928	2858	2855	2367	2210		2684a
No lime 8-12-8 (1)	2910	2803	2763	2890	2395	2119	2647	
Lime 8-12-8 (1)	2930	3010	2858	3000	2543	2610	2825	
Avg.	2920	2907	2811	2945	2469	2365		2736a

(Continued)

Table 18.—(Continued)

Soil amendment and fertilizer[1]	Extractable calcium (ppm)							
	1965	1967	1969	1972	1974	1978	$\overline{X}$	Avg.[2]
No lime 8-12-8 (1.5)	2953	2978	2868	2740	2340	2081	2660	
Lime 8-12-8 (1.5)	3225	4118	3770	3480	2498	2294	3231	
Avg.	3089	3548	3319	3110	2419	2188		2946a
No lime 8-12-8 (2)	3025	3575	3667	3500	2410	1832	3002	
Lime 8-12-8 (2)	3110	3508	3308	3110	2623	2379	3173	
Avg.	3068	3542	3489	3305	2517	2106		3088a
Season avg.—no lime[2]	2995	3119	2945	3095	2420	2153	2788a	
Season avg.—lime[2]	3011	3175	3106	3167	2572	2448	2913a	
Season avg.	3003	3147	3026	3131	2496	2301		2857

[1] Applied broadcast under the tips of the branches in February and disked lightly into the soil. Each tree also received .04 lb. of N per year of age in July.

[2] Averages followed by the same letter are not different at the .05 level of probability.

[3] Soil pH maintained at about 6.0 to 6.5. Some plots received sulphur applications broadcast evenly over the entire plot.

[4] Limed to the extent necessary to maintain soil pH above 6.5 and/or extractable calcium above 3,200 ppm.

[5] Numbers in parentheses denote pounds of fertilizer applied per tree per year of age.

Extractable magnesium in the soil was also unaffected by fertilizer or lime treatment (Table 19). All plots contained large amounts of extractable magnesium which remained fairly constant at these levels up to the last two seasons of sampling when they declined somewhat. In regard to possible effects of lime, it should be noted that only calcitic lime was used in this work.

The level of extractable phosphorus was affected by the kind and rate of fertilizer applied, particularly during the later seasons of sampling (Table 20). Control plots, or those receiving nitrogen alone, did not increase in extractable P with the passage of seasons, while those plots that received phosphate along with N or N and K did show some gain in extractable phosphorus. Furthermore, the extent of gain in extractable P was in direct proportion to the rate of fertilizer applied. The application of lime had no bearing on the average level of extractable P. Where 2 pounds of complete fertilizer per year of tree age had been applied annually for 13 years, the level of extractable P had increased from an average of 329 ppm to 633 ppm.

Some of the fertilizer treatments influenced the level of extractable potassium in the soil (Table 21). Only treatments containing K in the fertilizer, along with N and P, caused any increase in extractable K, and these increases occurred mainly during the later seasons of sampling. The increases were directly related to the rate of fertilization and were still widening at the end of the sampling period. Use of lime evidently did not influence potassium extractability. As with phosphorus, where 2 pounds of 8-12-8 per tree per year of age had been applied for 13 seasons, the level of extractable K increased from an average of 250 ppm to 417 ppm. (The K extractant was changed from 0.1 N HCl to 1.0 N NH_4OHC in 1970.)

In this study it was not possible to make organic matter determinations on the soil until the last two seasons of sampling. Results of these measurements are shown in Table 22. Evidently, neither of the treatment factors, fertilizer or lime, had any real effect on this component of the soil. There appeared to be some variation between seasons within most fertilizer and lime treatments with regard to organic matter content.

Although yields of fruit were increased markedly by some of the fertilizer treatments (Table 3), the average weight of individual fruits was not increased by fertilization (Table 23). This means the increases in fruit yields resulting from fertilizer use occurred in terms of the number of fruit produced per tree rather than as increases in the size of single fruits. Use of lime had no effect on fruit size, but did result in a significant variation in average fruit weight among seasons (data not shown).

Thickness of the fruit rind was increased by the use of fertilizer, but the response to treatment was so erratic that it was difficult to determine the plant nutrient or rate of application that was reponsible for the thicker rinds (Table 23). Unfertilized trees consistently produced fruit with the thinnest rinds. Rinds varied in thickness from year to year, but generally the rinds became thinner as the trees became older (data not shown). No influence of lime application on rind thickness was found at any time during the study.

Some slight differences in fruit rind color were usually apparent at the time the fruit was harvested each year in early December (Table 23). In terms of ''L'' values as measured with a Gardner color difference meter, the rinds of fruit from unfertilized trees had a slightly brighter orange color than those from other trees. Color differences were much greater early in the harvest season when fruit from the nitrogen treatments, especially at the heavy rates, showed much more green color in the rind than did fruit from the other plots. However, by the first week of December the fruit from all plots was fairly comparable in color. This is shown in the form of the ''a,'' ''b,'' and ''y'' values of the Gardner meter (Table 23). There was some variation in ''a'' values (which denote orange or red color) from year to year only (data not shown). No effect of lime application on fruit color was found at any time, whether judged visually or measured with the Gardner meter.

The amount of juice present in the fruit was unaffected by fertilizer treatment or lime application (Table 23). Juice content of the fruit did vary with season, however, ranging from an average of 45.8 percent in 1968 (younger trees) to 57.5 percent in 1973 (trees more mature).

Likewise, the degree of acidity of the fruit juice was not influenced by either fertilizer or lime applications (Table 23). This is shown in terms of pH of the juice and also in the titratable acidity of it. In both measurements, true variations were found only among seasons (data not shown). The pH varied from an average of 3.63 in 1972 to 4.19 in 1974, while the titratable acidity range was from 0.48 percent in 1967 to 0.78 percent in 1972 and 1976.

The soluble solids (primarily sugars) content of the juice was independent of fertilizer or lime treatment (Table 23). However, this quality factor was quite variable with season, showing relatively low values in fruit from the younger trees and increasing curvilinearly as the trees increased in age (data not shown). The range in soluble solids was from an average of 9.2 percent in 1967 (the first year of harvest) to 12.6 percent in 1972.

The ratio of soluble solids to titratable acid, which is an important aspect in determining fruit quality, was not affected by fertilizer or lime applications. As was true when soluble solids and titratable acid were considered as individual quality factors, the solids/acid ratio was affected only by season, varying from 13.7:1 in 1968 to a generally more desirable figure of 22:1 in 1975 (data not shown).

It is apparent from the fruit quality information in Table 23 that neither fertilizer applications of any type nor rate or lime use had any serious effects toward impairment of quality. These findings have important practical implications in view of the marked increases in tree growth and yield induced by some of the fertilizer treatments and the corresponding decreases brought about by use of lime.

Table 19.—Effects of soil amendment and fertilizer applications on the amount of extractable magnesium in the soil, 1965-78

Soil amendment and fertilizer[1]	Extractable magnesium (ppm)							
	1965	1967	1969	1972	1974	1978	$\bar{X}$	Avg.[2]
No lime[3] 0-0-0	772	906	867	905	718	558	788	
Lime[4] 0-0-0	689	792	880	955	740	626	810	
Avg.	821	849	874	930	729	592		799a
No lime 8-0-0 (1)[5]	710	787	791	951	730	630	767	
Lime 8-0-0 (1)	755	793	835	787	660	506	723	
Avg.	733	790	813	869	695	568		745a
No lime 8-0-0 (1.5)	747	830	823	839	724	575	756	
Lime 8-0-0 (1.5)	749	751	704	748	639	488	680	
Avg.	748	791	764	794	682	532		718a
No lime 8-0-0 (2)	743	816	714	806	688	572	723	
Lime 8-0-0 (2)	686	707	639	627	595	435	615	
Avg.	715	762	677	767	642	504		669a
No lime 8-12-0 (1)	806	834	803	865	776	634	786	
Lime 8-12-0 (1)	771	823	873	907	760	539	779	
Avg.	789	829	838	886	768	587		783a
No lime 8-12-0 (1.5)	724	723	694	1537	768	636	847	
Lime 8-12-0 (1.5)	704	729	708	790	689	526	691	
Avg.	714	726	701	1164	729	581		769a
No lime 8-12-0 (2)	746	783	782	821	752	599	747	
Lime 8-12-0 (2)	749	775	780	858	685	551	733	
Avg.	748	770	781	840	719	575		740a
No lime 8-12-8 (1)	750	725	785	865	757	635	753	
Lime 8-12-8 (1)	740	793	742	801	683	610	728	
Avg.	745	759	764	833	720	623		741a

(Continued)

Table 19.—(Continued)

Soil amendment and fertilizer[1]	Extractable magnesium (ppm)							
	1965	1967	1969	1972	1974	1978	$\overline{X}$	Avg.[2]
No lime 8-12-8 (1.5)	730	831	810	823	727	617	756	
Lime 8-12-8 (1.5)	844	889	966	969	659	523	808	
Avg.	787	865	888	896	693	570		782a
No lime 8-12-8 (2)	750	831	816	826	711	550	747	
Lime 8-12-8 (2)	794	867	780	834	695	509	747	
Avg.	772	849	798	830	703	530		747a
Season avg.—no lime[2]	748	807	789	924	735	601	767a	
Season avg.—lime[2]	766	792	791	828	681	531	732a	
Season avg.	757	800	790	876	708	566		750

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[1] Applied broadcast under the tips of the branches in February and disked lightly into the soil. Each tree also received .04 lb. of N per year of age in July.

[2] Averages followed by the same letter are not different at the .05 level of probability.

[3] Soil pH maintained at about 6.0 to 6.5. Same plots received sulphur applications broadcast evenly over the entire plot.

[4] Lime to the extent necessary to maintain soil pH above 6.5 and/or extractable calcium above 3,200 ppm.

[5] Numbers in parentheses denote pounds of fertilizer applied per tree per year of age.

Table 20.—Effects of soil amendments and fertilizer applications on the amount of extractable phosphorus in the soil, 1965-78

Soil amendment and fertilizer[1]	Extractable phosphorus (ppm)							
	1965	1967	1969	1972	1974	1978	$\bar{X}$	Avg.[2]
No lime[3] 0-0-0	351	298	366	433	302	344	349	
Lime[4] 0-0-0	347	286	348	463	287	292	337	
Avg.	349	292	357	448	295	318		343a
No lime 8-0-0 (1)[5]	357	281	336	404	266	317	327	
Lime 8-0-0 (1)	321	268	338	398	284	313	320	
Avg.	339	275	337	401	275	315		324a
Na lime 8-0-0 (1.5)	341	296	340	409	316	326	338	
Lime 8-0-0 (1.5)	348	292	330	390	295	297	325	
Avg.	345	294	335	400	306	312		332a
No lime 8-0-0 (2)	362	310	370	424	330	364	360	
Lime 8-0-0 (2)	338	275	330	389	295	325	325	
Avg.	350	293	350	407	313	345		343a
Na lime 8-12-0 (1)	325	284	368	501	334	472	381	
Lime 8-12-0 (1)	314	283	370	485	369	619	407	
Avg.	320	284	369	493	352	546		394b
No lime 8-12-0 (1.5)	337	302	408	499	363	572	413	
Lime 8-12-0 (1.5)	360	317	413	529	380	519	420	
Avg.	349	310	411	514	372	546		417bc
Na lime 8-12-0 (2)	341	316	408	574	398	665	450	
Lime 8-12-0 (2)	346	289	419	543	390	654	440	
Avg.	344	303	414	559	394	660		445c
Na lime 8-12-8 (1)	349	299	387	494	348	515	399	
Lime 8-12-8 (1)	367	316	389	504	355	511	407	
Avg.	358	308	388	499	356	513		403b

(Continued)

Table 20.—(Continued)

Soil amendment and fertilizer[1]	Extractable phosphorus (ppm)							
	1965	1967	1969	1972	1974	1978	$\bar{X}$	Avg.[2]
No lime 8-12-8 (1.5)	352	297	398	520	398	481	407	
Lime 8-12-8 (1.5)	323	284	406	547	391	597	425	
Avg.	338	291	402	534	395	539		416bc
No lime 8-12-8 (2)	327	296	411	592	451	661	456	
Lime 8-12-8 (2)	330	288	410	537	444	604	436	
Avg.	329	292	411	565	448	633		446c
Season avg.—no lime[2]	344	298	379	485	351	472	388a	
Season avg.—lime[2]	339	290	375	479	349	473	384a	
Season avg.	342	294	377	482	350	473		386

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[1] Applied broadcast under the tips of the branches in February and disked lightly into the soil. Each tree also received .04 lb. of N per year of age in July.

[2] Averages followed by different letters are different at the .01 level of probability.

[3] Soil pH maintained at about 6.0 to 6.5. Some plots received sulphur applications broadcast evenly over the entire plot.

[4] Limed to the extent necessary to maintain soil pH above 6.5 and/or extractable calcium above 3,200 ppm.

[5] Numbers in parentheses denote pounds of fertilizer applied per tree per year of age.

Table 21.—Effects of soil amendments and fertilizer applications on the amount of extractable potassium in the soil, 1965-78

Soil amendment and fertilizer[1]	Extractable potassium (ppm)							
	1965	1967	1969	1972	1974	1978	$\bar{X}$	Avg.[2]
No lime[3] 0-0-0	261	186	258	178	180	173	206	
Lime[4] 0-0-0	235	164	216	175	165	163	186	
Avg.	248	175	237	177	173	168		196a
No lime 8-0-0 (1)[5]	253	169	218	151	169	154	186	
Lime 8-0-0 (1)	246	171	229	158	161	151	186	
Avg.	250	170	224	154	165	153		186a
No lime 8-0-0 (1.5)	258	181	238	153	171	209	202	
Lime 8-0-0 (1.5)	249	156	205	151	175	155	182	
Avg.	254	169	222	152	173	182		192a
No lime 8-0-0 (2)	269	191	268	172	180	203	214	
Lime 8-0-0 (2)	240	183	216	159	197	178	196	
Avg.	255	187	242	166	189	191		205a
No lime 8-12-0 (1)	234	149	205	151	165	146	175	
Lime 8-12-0 (1)	245	154	206	143	175	178	184	
Avg.	240	152	206	147	170	162		180a
No lime 8-12-0 (1.5)	283	204	251	186	197	235	226	
Lime 8-12-0 (1.5)	253	191	223	160	187	175	198	
Avg.	268	198	237	173	192	205		212a
No lime 8-12-0 (2)	255	181	229	164	180	183	199	
Lime 8-12-0 (2)	250	159	226	135	178	169	186	
Avg.	253	170	228	150	179	176		193a
No lime 8-12-8 (1)	261	208	293	235	302	287	264	
Lime 8-12-8 (1)	255	183	281	235	254	339	258	
Avg.	258	196	287	235	278	313		261b

(Continued)

Table 21.—(Continued)

Soil amendment and fertilizer[1]	Extractable potassium (ppm) 1965	1967	1969	1972	1974	1978	$\overline{X}$	Avg.[2]
No lime 8-12-8 (1.5)	240	183	299	229	293	335	263	
Lime 8-12-8 (1.5)	214	176	263	231	259	335	246	
Avg.	227	180	281	230	276	335		255b
No lime 8-12-8 (2)	248	178	300	296	360	425	301	
Lime 8-12-8 (2)	251	209	324	285	348	409	304	
Avg.	250	194	312	291	354	417		303c
Season avg.—no lime[2]	256	183	256	192	218	235	223a	
Season avg.—lime[2]	244	175	239	183	220	225	214a	
Season avg.	250	179	248	188	219	230		219

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[1] Applied broadcast under the tips of the branches in February and disked lightly into the soil. Each tree also received .04 lb. of N per year of age in July.

[2] Averages followed by different letters are different at the .01 level of probability.

[3] Soil pH maintained at about 6.0 to 6.5. Some plots received sulphur applications broadcast evenly over the entire plot.

[4] Lime to the extent necessary to maintain soil pH above 6.5 and/or extractable calcium above 3,200 ppm.

[5] Numbers in parentheses denote pounds of fertilizer applied per tree per year of age.

Table 22.—Effects of soil reaction and fertilizer applications on the organic matter content of the soil, 1965-78

Soil amendment and fertilizer[1]	Soil organic matter (%)							
	1965	1967	1969	1972	1974	1978	$\bar{X}$	Avg.[2]
No lime[3] 0-0-0	—*	—*	—*	—*	1.64	1.50	1.57	
Lime[4] 0-0-0	—	—	—	—	1.48	1.44	1.46	
Avg.	—	—	—	—	1.56	1.47		1.52a
No lime 8-0-0 (1)[5]	—	—	—	—	1.65	1.50	1.57	
Lime 8-0-0 (1)	—	—	—	—	1.64	1.45	1.55	
Avg.	—	—	—	—	1.65	1.48		1.56a
No lime 8-0-0 (1.5)	—	—	—	—	1.55	1.35	1.45	
Lime 8-0-0 (1.5)	—	—	—	—	1.67	1.52	1.59	
Avg.	—	—	—	—	1.61	1.44		1.52a
No lime 8-0-0 (2)	—	—	—	—	1.61	1.44	1.52	
Lime 8-0-0 (2)	—	—	—	—	1.74	1.52	1.63	
Avg.	—	—	—	—	1.68	1.48		1.57a
No lime 8-12-0 (1)	—	—	—	—	1.65	1.42	1.54	
Lime 8-12-0 (1)	—	—	—	—	1.60	1.40	1.50	
Avg.	—	—	—	—	1.63	1.41		1.52a
No lime 8-12-0 (1.5)	—	—	—	—	1.65	1.39	1.52	
Lime 8-12-0 (1.5)	—	—	—	—	1.65	1.47	1.56	
Avg.	—	—	—	—	1.65	1.43		1.54a
No lime 8-12-0 (2)	—	—	—	—	1.54	1.41	1.47	
Lime 8-12-0 (2)	—	—	—	—	1.64	1.43	1.54	
Avg.	—	—	—	—	1.59	1.42		1.56a
No lime 8-12-8 (1)	—	—	—	—	1.61	1.49	1.55	
Lime 8-12-8 (1)	—	—	—	—	1.59	1.43	1.51	
Avg.	—	—	—	—	1.60	1.46		1.53a
No lime 8-12-8 (1.5)	—	—	—	—	1.54	1.38	1.46	
Lime 8-12-8 (1.5)	—	—	—	—	1.62	1.49	1.56	
Avg.	—	—	—	—	1.58	1.44		1.51a
No lime 8-12-8 (2)	—	—	—	—	1.59	1.53	1.56	
Lime 8-12-8 (2)	—	—	—	—	1.62	1.51	1.56	
Avg.	—	—	—	—	1.61	1.52		1.56a
Season avg.—no lime[2]	—	—	—	—	1.60	1.44	1.52a	
Season avg.—lime[2]	—	—	—	—	1.62	1.47	1.55a	
Season avg.	—	—	—	—	1.61	1.46		1.54

[1] Applied broadcast under the tips of the branches in February and disked lightly into the soil. Each tree also received .04 lb of N per year of age in July.

[2] Averages followed by the same letter are not different at the .05 level of probability.

[3] Soil pH maintained at about 6.0 to 6.5. Some plots received sulphur applications broadcast evenly over the entire plot.

[4] Limed to the extent necessary to maintain soil pH above 6.5 and/or extractable calcium above 3,200 ppm.

[5] Numbers in parentheses denote pounds of fertilizer applied per tree per year of age.

*Data not available for 1965, 1967, 1969 and 1972.

Table 23.—Effects of soil amendment and fertilizer applications on the quality of Washington navel oranges, 1967-79

Soil amendment and fertilizer treatments	Avg. wt. per fruit (g)	Rind thickness (mm)	Rind color[1]				Juice Content (%)	Juice pH	Titratable acidity (%)	Soluble solids (%)	Solids/ acid ratio
			L	a	b	y					
No lime	290	4.04	66.4	17.8	39.0	50.6	53.4	3.85	0.65	11.3	17.6
Lime	283	4.03	66.4	17.1	38.9	50.6	53.3	3.82	0.66	11.4	17.5
Significance (1%)	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
0-0-0	296a[3]	3.90a[3]	67.1a[3]	17.2	39.3	51.4	53.2	3.84	0.65	11.2	17.5
8-0-0 (1)[2]	295a	4.12b	66.5bcd	17.2	38.9	50.7	53.6	3.85	0.65	11.3	17.6
8-0-0 (1.5)	278b	4.00ab	66.1cd	17.5	38.9	50.0	53.8	3.81	0.66	11.4	17.5
8-0-0 (2)	280b	4.07b	66.3bcd	18.2	38.2	50.3	53.8	3.84	0.66	11.5	17.7
8-12-0 (1)	286ab	4.04b	66.6abc	17.4	39.2	51.1	53.2	3.82	0.67	11.4	17.5
8-12-0 (1.5)	278b	4.01ab	66.2cd	17.4	38.9	50.8	53.3	3.84	0.65	11.4	17.7
8-12-0 (2)	287ab	4.07b	66.0d	17.5	39.4	49.3	52.6	3.85	0.64	11.4	18.2
8-12-8 (1)	297a	4.11b	66.8ab	17.1	39.2	51.0	53.3	3.85	0.66	11.2	17.1
8-12-8 (1.5)	283ab	4.00ab	66.5bcd	17.0	38.9	50.6	53.5	3.82	0.67	11.3	17.1
8-12-8 (2)	288ab	4.06b	66.4bcd	17.9	38.9	50.5	53.6	3.85	0.65	11.4	17.8
Significance (1%)	**	**	**	ns	ns	ns	ns	ns	ns	ns	ns

---

[1] Gardner color difference meter values; standard white tile: L = 91.6; a = −1.3; b = +0.1.

[2] Numbers in parentheses denote pounds of fertilizer applied per tree per year of age.

[3] Values within columns followed by different letters are different at the .01 level.

In assessing the overall performance of the trees at the end of the experimental period, it became apparent that the yield of fruit was influenced to some extent by prevailing soil conditions, as well as by fertilizer and amendment applications. These relationships are shown in Table 24. Within the range of soil reaction among the various plots existing in this study, the highest yields were obtained from the trees growing on the more acid soil. Furthermore, the plots with the higher levels of soil calcium and/or magnesium were somewhat less efficient in fruit production than those with lower levels of these elements. Perhaps the most important points to be derived from the data in Table 24 are the importance of providing high levels of available phosphorus in the soil to insure high fruit production and the highly beneficial effects of maintaining high levels of available potassium.

Apparently, accumulation of phosphorus in the foliage was not dependent on high levels of soil P, and there was little association betwen foliar potassium and soil K (Table 24). It may be recalled that in this study the foliar levels of plant nutrients were determined on a concentration basis—percent of dry weight—and not on a total uptake basis. Soil calcium exerted only a small influence on foliar P, but foliar K was more closely related to the level of soil Ca. Some connection was seen between soil Ca and foliar Ca, but the accumulation of Mg in the leaves was definitely depressed by high levels of soil Ca. This depression was also true for leaf manganese, but the accumulation of zinc by the leaves appeared to be fostered by soil Ca. As was true for calcium, there was a weak negative relationship between soil magnesium and the concentration of the element found in the leaves.

Soil reaction had no influence on the accumulation of phosphorus in the leaves (Table 24). However, both the potassium and calcium concentrations in the foliage were strongly influenced by soil pH. Foliar Ca, Mg, and Mn were all inversely related to soil pH, while zinc accumulation was unrelated to soil reaction.

Evidently the soil reaction was negatively related to the soluble solids content of the fruit, but soil phosphorus was positively related to the solids level (Table 24). Soil K showed no association with soluble solids, while both soil Ca and Mg were inversely related to the soluble solids content of the fruit.

The titratable acid content of the fruit was increased by the more acid soil as well as by the higher levels of soil phosphorus (Table 24). The levels of soil K and Ca apparently exerted some influence on fruit acid levels, but soil Mg was not effective in this regard.

The data in Table 25 indicate that fruit production was associated with several other characteristics of the fruit and foliage. There was some relationship, although negative, between fruit production and the accumulation of both N and P in the foliage. A closer relationship, but also negative, was shown between the K concentration in the leaves and yield of fruit. Foliar nutrients showing positive associations with yield were Ca,

Table 24.—Relationship between nutrient levels available[1] in the soil and various plant responses by Washington navel orange trees, 1965-79

Soil and plant variables	r value
Soil pH and yield[2]	−0.39**
Soil Ca[3] and yield[2]	−0.34**
Soil Mg[3] and yield[2]	−0.17**
Soil P[3] and yield[2]	0.59**
Soil K[3] and yield[2]	0.36**
Soil P[3] and foliar p[4]	−0.17**
Soil K[3] and foliar K[4]	0.10*
Soil Ca[3] and foliar p[4]	−0.09*
Soil Ca[3] and foliar K[4]	0.27**
Soil Ca[3] and foliar Ca[4]	−0.16**
Soil Ca[3] and foliar Mg[4]	−0.38**
Soil Ca[3] and foliar Mn[5]	−0.33**
Soil Ca[3] and foliar Zn[5]	0.36**
Soil Mg[3] and foliar Mg[4]	−0.19**
Soil pH and foliar p[4]	0.03
Soil pH and foliar K[4]	0.32**
Soil pH and foliar Ca[4]	−0.19**
Soil pH and foliar Mg[4]	−0.35**
Soil pH and foliar Mn[5]	−0.56**
Soil pH and foliar Zn[5]	0.12
Soil pH and soluble solids[6] in fruit	−0.28**
Soil P[3] and soluble solids[6] in fruit	0.41**
Soil K[3] and soluble solids[6] in fruit	0.04
Soil Ca[3] and soluble solids[6] in fruit	−0.28**
Soil Mg[3] and soluble solids[6] in fruit	−0.10*
Soil pH and acid content[6] in fruit	−0.27**
Soil P[3] and acid content[6] in fruit	0.57**
Soil K[3] and acid content[6] in fruit	0.14*
Soil Ca[3] and acid content[6] in fruit	−0.15*
Soil Mg[3] and acid content[6] in fruit	−0.08

[1] Determined as extractable levels by LSU Soil Testing Laboratory.
[2] Determined as pounds per tree per year.
[3] Determined as ppm of air-dry soil.
[4] Determined as percent dry weight of leaf tissue.
[5] Determined as ppm of dry leaf tissue.
[6] Determined as percent of juice.
*Significant at the .05 level of probability.
**Significant at the .01 level of probability.

Mg, Mn, and Zn. In this connection, the larger trees with the lower concentrations of N, P, and K in the foliage, which also produced the most fruit, probably represent the more desirable and more normal nutritional status of good navel orange trees. Other nutrients that tended to accumulate in the foliage of the highest-yielding trees were probably present in concentrations somewhat above that required for normal growth and production.

There was some relationship between foliar Ca and foliar Mg, although the connection was not very impressive (Table 25). As expected, the

Table 25.—Relationships between foliar nutrient levels[1] and various other plant responses by Washington navel orange trees, 1965-79

Foliar nutrient levels and other plant variables	r value
Foliar N and yield[2]	−0.13**
Foliar P and yield[2]	−0.15**
Foliar K and yield[2]	−0.46*
Foliar Ca and yield[2]	0.32**
Foliar Mg and yield[2]	0.31**
Foliar Mn and yield[2]	0.43**
Foliar Zn and yield[2]	0.25**
Foliar Ca and foliar Mg	0.12**
Foliar K and foliar Mg	−0.10**
Foliar K and foliar Ca	−0.42**
Foliar Ca and foliar Mn	0.25**
Foliar Ca and foliar Zn	0.23**
Folair Mg and foliar Mn	0.34**
Foliar Mg and foliar Zn	−0.02
Foliar Mn and foliar Zn	0.31**
Foliar N and soluble solids[3] in fruit	−0.32**
Foliar P and soluble solids[3] in fruit	−0.25**
Foliar K and soluble solids[3] in fruit	−0.54**
Foliar Ca and soluble solids[3] in fruit	0.42**
Foliar Mg and soluble solids[3] in fruit	0.19**
Foliar Mn and soluble solids[3] in fruit	0.30**
Foliar Zn and soluble solids[3] in fruit	0.23**
Foliar N and acid content[3] in fruit	−0.38**
Foliar P and acid content[3] in fruit	−0.15**
Foliar K and acid content[3] in fruit	−0.12**
Foliar Ca and acid content[3] in fruit	0.29**
Foliar Mg and acid content[3] in fruit	0.10**
Foliar Mn and acid content[3] in fruit	−0.10*
Foliar Zn and acid content[3] in fruit	−0.24**

[1] Determined as percent of dry leaf tissue.

[2] Determined as pounds per tree per year.

[3] Determined as percent of juice.

*Significant at the .05 level of probability.

**Significant at the .01 level of probability.

association between foliar K and Mg accumulation was negative. The same association, but much more marked, was found between accumulations of K and Ca in the leaves. In contrast, Ca and Mn showed a mutually positive influence in foliar accumulation. This type of relationship was also found between Ca and Zn and between Mg and Mn. No relationship was found between the accumulation of Mg and Zn in the leaves, but concentrations of foliar Mn and Zn were fairly closely related.

The level of N in the leaves apparently was inversely related to the soluble solids content of the fruit (Table 25). The same association was found between foliar P and soluble solids, and between foliar K and solids. Again, the larger trees that were apparently diluting the concentration of N, P and K in the foliage somewhat, not only produced the most fruit but also produced the highest soluble solids in the fruit. This relationship is reflected in the highly significant correlation of 0.66** between yield and soluble solids. The other elements, Ca, Mg, Mn, and Zn, tended to accumulate somewhat in these trees. Accordingly, the levels of these elements in the leaves were all positively related to the soluble solids content of the fruit.

Foliar N was clearly associated with the acid content of the fruit in a negative manner (Table 25). A similar, though less striking, association was found between foliar P and fruit acid and also between foliar K and acid content. Foliar Ca and Mg were both positively related to the acid level in the fruit, but Mn and especially Zn displayed a negative relationship between accumulation in the foliage and the production of acid in the fruit. The larger, higher-yielding trees containing lower levels of foliar N, P, and K also produced the most acid in the fruit. Apparently, however, the associations of foliar Mn and Zn to fruit acid did not follow the same pattern as in the case of soluble solids production. The degree of association between the production of fruit acid and yield, although still highly significant, was only 0.18**.

Summary

Washington navel oranges grown on Mississippi River Alluvial soil (Commerce-Mhoon silt loam—silty clay loam) at the Plaquemines Parish Experiment Station from 1965 to 1980 made significant responses to fertilizer and lime applications. The greatest response was obtained in terms of tree growth and yield from the use of complete fertilizer at the heaviest rate tested (2 pounds of an 8-12-8 grade per tree per year of age applied in February plus 0.4 pound of N per tree per year of age applied in July). Other fertilizer mixtures lacking in phosphorus and/or potassium were less effective than the complete fertilizers when used at comparable rates. The use of nitrogen alone at the heavier rates studied was clearly detrimental to yield and showed a marked effect on delaying fruit maturity.

Application of lime in conjunction with fertilizer treatments to maintain the soil pH above 6.5 had a depressing effect on tree growth and yield. The use of sulphur to keep some of the plots around pH 6.0 was apparently not harmful to the trees.

In spite of large increases in yield that resulted from some of the more effective fertilizer applications, there was no impairment in the quality of fruit due to any treatment when quality was measured in terms of fruit size, color, juice content, soluble solids content, acid content, or solids/acid ratio. Furthermore, lime applications had no measurable influence on fruit quality.

The accumulation of plant nutrients in foliage was definitely affected by the type and rate of fertilization. Large variations in foliar nutrient levels were found to occur from one season to another. Application of lime to the soil had little influence on the accumulation of any nutrient in the leaves except manganese.

The application of lime, at rates used in this study, did not cause major changes in soil reaction or in levels of extractable calcium. Other soil characteristics such as extractable magnesium, potassium, and phosphorus were apparently not affected by lime applications. Use of sulphur was successful in altering the soil pH slightly in certain plots. The variation in levels of all nutrients extracted from the soil from season to season was striking.

The levels of extractable phosphorus and potassium in the soil were increased considerably during a 13-year period by applying these elements annually in a complete fertilizer at a fairly heavy rate. Apparently these were the only elemental accumulations affected in the soil by fertilization during the period of the experiment.

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esponse of Soybeans to Planting Date n Southwest Louisiana

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RESPONSE OF SOYBEANS TO PLANTING DATE IN SOUTHWEST LOUISIANA

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Climatic conditions in southwest Louisiana are generally favorable for planting soybeans (*Glycine max* L. Merr.) from April through July. Since soybeans grown in the South are determinate in their growth habit and flower according to day length and temperature, planting date is important in determining yield potential.

Planting at optimum dates provides a long growing season which encourages the production of plants with high yield potential. In large farm operations, extending the planting season over a long period is desirable for efficient use of labor and machinery. Problems can occur, however, from planting too early or too late. Poor seed germination and reduced plant vigor due to soil and air temperatures, weeds, insects, diseases, and premature flowering can result in loss of yield potential at early planting dates. Late planting can also be detrimental because plants are exposed to a shorter growing season and often lack the size to support a large seed crop.

Soybean yield varies with planting date since varieties differ in flowering date, growth habit, and response to growing conditions. Studies were initiated in southwest Louisiana at the Rice Experiment Station to study yield and agronomic performance of four widely grown soybean varieties as affected by planting date. Information on the effect of planting date on soybean performance would be useful in variety selection especially where weather conditions preclude planting at the optimum time or where replanting late in the season is necessary.

Literature Review

Soybeans can produce good yields when planted over a wide range of dates. The soybean plant has an advantage over other agronomic crops because it is photoperiod sensitive and changes from vegetative to flowering in direct response to day length. Southern adapted varieties initiate flowering more rapidly when there are less than 14 hours between sunrise and sunset. (*10*)[3]. Determinate varieties grown in the South make little vegetative growth after flowering is initiated thus soybean plant size is dependent on growing conditions and day length. Planting date is, therefore, an important factor in determining plant size and yield potential.

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Day length and low temperature are the major restrictions to planting early in the South. June 22 is the longest day of the year after which days become shorter. Since soybeans are short day plants, they will flower as the day length shortens after June 22. However, if soybeans are planted too early, the critical day length which triggers flowering is reached prior to June 22 resulting in premature flowering. Gray (*4*) working with soybeans in the 1950's in Louisiana observed that "crushing" types planted in March and April produced and shedded blooms and pods throughout the spring and summer. 'Lee' was observed to have maturing pods as well as blooms on June 23. Early plantings may also encourage potential weed problems because of slower soybean seed germination and seedling growth. As a result, mature plants are shorter and lower yielding as compared to those planted at an optimum time (*4, 6, 9, 11*).

Soybean varieties differ in response to day length and, consequently, to varying planting date. For most varieties, optimum planting time is from May through early June (*1, 3, 6, 9, 11*). Significant yield reductions are often associated with planting at nonoptimum times. 'Davis', however, has been shown to be more consistent than other varieties at producing high yields when planted at nonoptimum planting dates (*1, 11*).

Row spacing has been shown to influence yield responses to planting date. In northeast Louisiana Boquet *et al*. (*1*) reported higher grain yields at row spacings of 10 and 20 inches vs. 40 inches whether soybean varieties were planted on optimum or nonoptimum planting dates. Yield responses were greatest for soybeans planted at later dates (late June through early July). Other researchers have reported that narrow and wide row spacing were equally productive when soybeans were planted at optimum dates (*3, 7*).

Length of the growing season (days from planting until maturity) is reduced as planting date is delayed. For a given planting date the effect of reduction in length of the growing season is greater for early maturing varieties than later maturing varieties since following of early varieties is triggered much sooner after planting (*6*). Consequently, the yield of early varieties is generally reduced more with delay in planting compared to late varieties.

Plant height and lower pod height of early varieties are often reduced more with delay in planting than those of late varieties. This can account for the higher yields generally observed for late varieties planted at nonoptimum dates providing the growing season is of sufficient length (*10*). Lodging has been reported to be more severe when planting is delayed (*10*, *11*).

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[3] Italic numbers in parentheses refer to Literature Cited, page 12.

Parker *et al*. (*9*) reported highest soybean seed weight when plantings were made in late May or early June. Seed quality has been shown to be higher for late plantings than early plantings in Missouri (*5*) and in Northeast Louisiana (*2*). Similar responses would be expected under high humidity and high temperature conditions of southwest Louisiana. Joshi (*8*) reported that soybeans planted by or after mid-June in Maryland generally were more susceptible to corn earworm (*Heliothis zea* Boddie) than earlier plantings.

Materials and Methods

Field experiments were conducted during 1978-80 on an Acadia silt loam (Aeric Ochraqualf) soil at the Rice Experiment Station, Crowley, La. to study responses of soybeans to planting date. Soil tests from the experimental area indicated: pH = 5.8, P = 19 ppm, and K = 55 ppm. Four cultivars, 'Dare' (Maturity Group V), 'Tracy' and 'Davis' (Maturity Group VI), and Bragg (Maturity Group VII) were evaluated. Attempts were made to plant varieties in mid-April, mid-May, mid-June, and mid-July. Weather conditions did not allow for plantings to be made at a closer range of dates. Planting dates in 1978, 1979, and 1980 were: April 21, 17, 22; May 25, 10, 29; June 19, 13, 20; and July none, 31, 31, respectively.

A split plot experimental design with four replications was used. Soybean varieties were whole plots with planting dates as subplots. Subplots consisted of six 32-inch rows, 35 feet in length. All plots were planted with a conventional 2-row planter at approximately 12 seed per foot of row (about 55 to 65 pounds of seed per acre) at a 1- to 2-inch depth. Since soybeans had been grown in the area previously, seed was not inoculated. Fungicide seed treatment was not used. Fertilizer was applied broadcast and incorporated prior to planting at a rate of 0-60-60 (N-P_2O_5-K_2O). Weeds were controlled with preemergence and postemergence herbicides and cultivation. The four center rows from each plot were combine harvested after maturity. Grain yields were adjusted to 13 percent moisture and reported in bushels per acre based on 60 pounds per bushel. Test weights were determined using a standard pint Winchester bushel. Plant height, lower pod height, and lodging were determined at maturity.

Combined analysis of variance for the 3 years (1978-80) was used for the April, May, and June planting dates. A 2-year (1979-80) combined analysis was used for April, May, June, and July planting dates. Duncan's Multiple Range test was used to detect differences among main effect means and Fisher-protected LSD was used for interaction mean comparisons.

Results and Discussion

Grain Yields

Rainfall quantities (April through September) for 1978, 1979, and 1980 at the Rice Experiment Station, Crowley, deviated from the 50-year mean by −4.3, +8.3, and +3.9 inches, respectively (Table 1). The season total for 1980, however, is misleading because of an abnormally large amount of rain received in May (16.9 inches). The largest moisture deficit of the 3 years occurred in July and August in 1980. Performance of soybeans planted in mid-April, mid-May, and mid-June were compared over three growing seasons (1978-1980). Averaged over the 3 years, yields for all varieties were highest when planted in mid-May and lowest when planted in mid-April (Table 2). Average yields at the mid-May planting date ranged from a high of 35.3 bu/A in 1979 to a low of 19.6 bu/A in 1980. Yield differences among years were related to rainfall amount and distribution. Delaying planting from mid-May until mid-June reduced yields 10.6 bu/A which corresponds to a decrease of approximately 0.4 bu/A per day. The sharp yield decrease associated with delaying planting emphasizes the importance of planting in May or early June. The extremely low yields observed for Dare and Tracy planted in mid-April were related to premature flowering. Both Davis and Bragg produced highest yields when planted in mid-April and in mid-June. Dare yielded lowest of the varieties tested on all planting dates.

The 1979-1980 yields for the four planting dates are presented in Table 3. Yields were highest for all varieties when planted in mid-May and lowest when planted in mid-July. Soybeans planted at the optimum time in mid-May yielded 16.7 bu/A higher than those planted in mid-April and 23.1 bu/A higher than those planted in mid-July. Yields of Dare and Tracy were more adversely affected by nonoptimum planting date compared to the other varieties. Davis and Bragg were least affected by planting date and yields were higher than those of the other varieties at both early and late planting dates. Even so, yields of both Davis and Bragg at mid-April and mid-July planting dates were too low to be profitable.

Averaged over varieties, delaying planting from mid-May until mid-July reduced yields 23 bu/A (a 9 bu/A decrease from mid-May to mid-June and a 14 bu/A decrease from mid-June to mid-July). This corresponds to a decrease in yield of approximately 0.4 bu/A for each day planting is delayed after mid-May (0.3 bu/A loss from mid-May to mid-June and 0.5 bu/A loss from mid-June to mid-July). Rainfall accumulation from June through September 1979 was nearly twice that received in 1980 (21 vs. 11 inches) (Table 1). Consequently, yield reductions associated with the late planting date was more severe in 1980. Averaged over varieties, yields of soybeans planted in mid-May in 1980 were 15.7 bu/A lower than those planted in 1979.

Table 1.—Rainfall received during growing seasons at the Rice Experiment Station, Crowley, La, 1978-1980

Year	Month						
	April	May	June	July	Aug.	Sept.	Total
	Inches						
1978	2.28	2.51	6.75	6.96	3.91	3.41	25.82
1979	9.36	8.38	0.33	8.88	6.13	5.43	38.51
1980	5.85	16.91	1.55	4.76	2.25	2.66	33.98
Normal[1]	4.13	5.13	4.80	6.24	5.73	4.10	30.13

[1] Determined from Davis, J. H., *et al*. Fifty Years of Weather at LSU Rice Experiment Station, Crowley, La., 1910-1959. Inclusive. LSU Agricultural Experiment Station Circular No. 69.

Table 2.—Effect of planting date on yield of four soybean varieties grown at the Rice Experiment Station, Crowley, La, 1978-1980

Variety	Planting date[1]			
	Mid-April	Mid-May	Mid-June	Average
	bu/A			
Dare	10.5	21.9	14.3	15.6c[2]
Davis	19.6	29.3	17.0	22.0a
Tracy	10.8	28.8	15.4	18.4b
Bragg	17.3	28.2	19.3	21.6a
Average	14.5c	27.1a	16.5b	

[1] LSD (.05) = 3.0 bu/A for variety x planting date interaction.

[2] Means followed by the same letter are not significantly different ($P<.05$) using DMRT.

Table 3.—Effect of planting date on yield of four soybean varieties grown at the Rice Experiment Station, Crowley, La, 1979-1980

Variety	Planting date[1]				
	Mid-April	Mid-May	Mid-June	Mid-July	Average
	bu/A				
Dare	6.2	23.0	15.3	3.0	11.9c[2]
Davis	16.1	30.6	19.8	6.2	18.2a
Tracy	6.2	29.1	16.4	2.9	13.6b
Bragg	14.5	26.9	21.9	5.1	17.1a
Average	10.7c	27.4a	18.4b	4.3d	

[1] LSD (.05) = 2.7 bu/A for variety x planting date interaction.

[2] Means followed by the same letter are not significantly different ($P<.05$) using DMRT

Table 4.—Effect of planting date on test weight of four soybean varieties grown at the Rice Experiment Station, Crowley, La, 1978-1980

Variety	Planting date[1] Mid-April	Mid-May	Mid-June	Average
	lb/bu			
Dare	51.2	54.4	55.4	53.6c[2]
Davis	52.7	55.9	53.7	54.1c
Tracy	54.8	55.7	54.6	55.0b
Bragg	56.9	57.8	56.9	57.2a
Average	53.9c	56.0a	55.2b	

[1] LSD (.05) = 1.5 lb/bu for variety x planting date interaction.
[2] Means followed by the same letter are not significantly different (P<.05) using DMRT.

Table 5.—Effect of planting date on test weight of four soybean varieties grown at the Rice Experiment Station, Crowley, La, 1979-1980

Variety	Planting date[1] Mid-April	Mid-May	Mid-June	Mid-July	Average
	lb/bu				
Dare	49.3	54.3	55.0	48.7	51.8c[2]
Davis	52.8	57.2	55.0	49.0	53.5b
Tracy	55.2	56.4	55.4	49.6	54.2b
Bragg	56.5	58.1	58.5	49.3	55.6a
Average	53.5b	56.5a	56.0a	49.1c	

[1] LSD (.05) = 1.9 lb/bu for variety x planting date interaction.
[2] Means followed by the same letter are not significantly different (P<.05) using DMRT.

Test Weight

The yield differences among planting dates were reflected in lower seed quality as measured by test weight. Test weight is an important determinant in both grade and price of soybeans marketed. A minimum test weight of 56 lb/bu is required to make a US No. 1 grade. Soybean test weights were similar for the varieties when planted in mid-May and mid-June but were significantly lower when planted in mid-April and mid-July (Tables 4 and 5). At the mid-April planting date and averaged across planting dates, seed quality as measured by test weight was lowest for Dare and highest for Bragg.

The effect of early planting on seed quality and on yield potential of earlier maturing varieties raises questions concerning the common practice in the South of planting early maturing varieties before later maturing ones. In northeast Louisiana, yield of 'Forrest' was higher when planted in mid-May than on May 1 (*1*). Later maturing varieties produced maximum yields when planted on May 1 and had a longer optimum planting season than that of Forrest. Results of these studies indicate the importance of variety selection where soybeans are planted earlier than mid-May.

Agronomic Characteristics

The length of the growing season decreased for each variety as planting date was delayed (Tables 6 and 7). For each month planting was delayed, the length of the growing season was reduced an average of 23 days. The soybean varieties grown were determinant types and are photoperiod and temperature sensitive. Consequently, when these varieties were planted early, the number of days to maturity was greater than for the same varieties planted at a later date. The longer growing season at early planting dates resulted in longer exposure to possible adverse growing conditions which

Table 6.—Effect of planting date on agronomic characteristics of four soybean varieties grown at the Rice Experiment Station, Crowley, La, 1978-1980

Planting date and variety	Length of growing season (days)[1]	Plant ht. (in)	Lower pod ht. (in)	Lodging[2]
Mid-April				
Dare	142	17.2	2.6	1.0
Davis	155	21.6	4.0	1.0
Tracy	173	16.8	2.6	1.0
Bragg	181	20.5	3.6	1.0
Average	163a[3]	19.0c	3.2c	1.0b
Mid-May				
Dare	125	22.0	3.7	1.0
Davis	141	27.7	4.4	1.0
Tracy	146	28.2	4.4	1.0
Bragg	152	31.3	4.7	1.1
Average	141b	27.3a	4.3a	1.0b
Mid-June				
Dare	115	21.5	3.3	1.4
Davis	122	25.0	4.3	1.4
Tracy	120	23.8	3.8	1.3
Bragg	126	26.8	4.1	1.3
Average	121c	24.3b	3.9b	1.4a

[1] Days from planting to maturity.

[2] 1 = no lodging, 5 = all plants down.

[3] Means in each column followed by the same letter are not significantly different ($P < .05$) using DMRT.

affected both yield and seed quality.

Plant height of the varieties at maturity ranked as follows: mid-May > mid-June > mid-April > mid-July (Tables 6 and 7). Shorter plant heights for the mid-April planting date (approximately 19 inches) were related to unfavorable growing conditions early in the season. "Dwarfing out" related to premature flowering was noted for Dare and Tracy. Mid-April planted soybeans were never able to recover from the early season stress. Reduced plant height at the mid-July planting date was related to the short growing season. Grain yields were highly correlated (r = 0.93**) with plant height for all varieties and planting dates. The taller more branching plants produced highest yields and shorter plants the lowest yields.

Lower pod heights were similar for soybeans planted in mid-May and mid-June but were lower for those planted in mid-April and mid-July

Table 7.—Effect of planting date on agronomic characteristics of four soybean varieties grown at the Rice Experiment Station, Crowley, La, 1979-1980

Planting date and variety	Length of growing season (days)[1]	Plant ht. (in)	Lower pod ht. (in)	Lodging[2]
Mid-April				
Dare	146	16.0	2.5	1.0
Davis	160	21.5	3.5	1.0
Tracy	173	15.3	2.5	1.0
Bragg	181	19.6	3.3	1.0
Average	165a[3]	18.1c	2.9b	1.0
Mid-May				
Dare	128	22.4	3.4	1.0
Davis	140	29.5	4.5	1.0
Tracy	145	28.9	4.0	1.0
Bragg	155	32.4	4.5	1.0
Average	142b	28.3a	4.1a	1.0
Mid-June				
Dare	110	21.0	3.4	1.0
Davis	119	25.3	4.4	1.0
Tracy	120	25.3	4.1	1.0
Bragg	126	28.3	4.5	1.0
Average	119c	24.9b	4.1a	1.0
Mid-July				
Dare	91	14.0	1.8	1.0
Davis	97	13.9	2.0	1.0
Tracy	92	12.8	1.6	1.0
Bragg	104	15.3	1.9	1.0
Average	96d	14.0d	1.8c	1.0

[1] Days from planting to maturity.

[2] 1 = no lodging, 5 = all plants down.

[3] Means in each column followed by the same letter are not significantly different ($P<.05$) using DMRT.

(Tables 6 and 7). The corresponding lower yields reported for soybeans planted in mid-July were not only related to shorter and less branched plants but were also related to higher yield losses since the combine was unable to harvest the lower pods. Lodging was not greatly affected by planting date.

Conclusions

Results of this study show the importance of planting date on soybean performance. As in previous studies, the optimum planting date for soybeans in southwest Louisiana was found to be during the month of May. Problems associated with April planting of soybeans in these studies were poor seed germination and reduced vigor due to cool, wet soil conditions, early season weeds, insects, and diseases, and lower seed yield and quality. Premature flowering of early planted soybeans resulted in "dwarfing out." Soybean yields declined approximately 0.3 bu/A for each day planting was delayed from mid-May to mid-June and 0.5 bu/A for each day delay from mid-June to mid-July. Davis and Bragg performed best of the varieties tested when planted in mid-April but even for these varieties yields were low. The lower yields at the April planting compared with the May and June plantings suggest that it would be more advantageous to delay planting until the later dates when conditions for plant growth are more favorable. Later maturing varieties would be more desirable if planting is delayed or replanting is necessary after mid-June.

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Evaluation of Pensacola Bahiagrass and Alicia Bermudagrass With and Without Interplanted Ryegrass and Red Clover

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Louisiana Agricultural Experiment Station, Doyle Chambers, Director
Louisiana State University Agricultural Center, Alvin C. Harper, Chancellor

The Louisiana Agricultural Experiment Station follows a nondiscriminatory policy in programs and employment

Evaluation of Pensacola Bahiagrass and Alicia Bermudagrass With and Without Interplanted Ryegrass and Red Clover

Charles R. Montgomery,[1] Billy D. Nelson,[1] Marvin Allen,[2]
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Warm-season perennial grasses play an important role in providing grazing and harvesting hay for Louisiana's livestock industry. Many farmers rely on perennial grasses to provide grazing in the summer and annual forages for grazing during winter months. In the past this system of grassland farming has required two or more separate fields. With increasing demands on land and the high cost of seedbed preparation, farmers may benefit from sodseeding perennial pastures with annuals to extend the productive period. This system offers the advantage of providing two grazing seasons on the same area and may significantly reduce the acreage required per animal unit.

Winter annual grasses and legumes have been studied extensively in pure swards, but only limited data are available on their productivity and quality potentials when grown in a warm-season perennial grass sod. Information is also needed on the extent to which the grazing season may be expanded by incorporation of an annual grass of legume and on subsequent effects of interplanted annuals on performance of the perennial grasses.

An experiment was conducted over 4 years with two warm-season perennial grasses, Pensacola bahiagrass and Alicia bermudagrass, grown in pure swards and sodseeded with ryegrass or red clover with the following objectives:

(1) To measure length of extension of forage productivity resulting from incorporating an annual grass or legume in perennial sods.
(2) To determine forage quality of pure perennial grass stands and of mixed stands (with annuals) throughout the entire growing season.
(3) To study agronomic performance characteristics, such as total yield, yield distribution, stand compatibility, and persistency

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REVIEW OF LITERATURE

Data available on performance of the grasses and legume used in this study indicate that all are well adapted as pasture crops in Louisiana.

Pensacola bahiagrass was first introduced into the United States in 1913. Ward and Watson (*12*)[3] summarized some of the more important aspects of bahiagrass as a forage crop. Bahiagrass is popular in the south because it is (a) tolerant of a wide range of soil conditions; (b) resistant to encroachment of weeds; (c) easily established by seeding; (d) relatively free from attack by insects and disease organisms; (e) moderately productive in soils of low fertility, and (f) tolerant of close grazing. Forage quality of bahiagrass was highest in early spring, but by mid-summer the percentage of cell wall constituents (CWC) was sufficiently high to suggest that animal intake would be limited. Dry forage yields of 15,000 pounds per acre have been reported when harvested at 4-week intervals (*5*).

Alicia is a hybrid bermudagrass established by sprigging plant material. Allen (*1*) reported highest total dry matter yield with Alicia bermudagrass, followed by Coastal, Coastcross-1, and Common bermudagrass and Pensacola bahiagrass when harvested at 4-week intervals. A more uniform yield distribution was observed with Pensacola bahiagrass, and it was concluded that Pensacola could be better utilized for grazing than for haying. Alicia had the highest structural carbohydrate percentages, while Pensacola and Coastcross-1 had the highest in vitro digestible dry matter (IVDDM) values. Nelson (*6*) harvested Alicia and three other bermudagrass cultivars at 35-day intervals and reported these season-average acid detergent fiber (ADF) percentages: Common—32.3, Coastal—34.2, Alicia—34.9, and Coastcross 1—37.3.

Marchant (*4*) compared oats and ryegrass seeded in Pensacola bahiagrass and Coastal bermudagrass for effects on average daily gain, average number of days of grazing, and summer growth of the perennials. He reported no significant effect, as measured by annual beef production per acre, on performance of summer perennials resulting from sodseeding of oats or ryegrass the previous winter There was no difference in animal gains per acre between sodseeded oats and ryegrass. The winter annuals produced an average of 36 percent fewer animal grazing days when planted in bahiagrass sod than when planted in bermudagrass sod.

Robinson (*8*) pointed out that the success of fall sodseeded crops is closely linked to rainfall and temperature patterns. Most research results suggest that only limited grazing is provided in late fall or winter because of competition from the summer perennials, with most of the growth occurring after February 15 (*14*).

Welch et al (*13*) noted that first-harvest bermudagrass yields decreased as rate of nitrogen applied to sod-seeded rye increased. They concluded that Coastal bermudagrass yield reductions were positively related to

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[3] Italic numbers in parentheses refer to Literature cited, page 19.

increased density of the over-sown crop. To increase first-harvest Coastal yields, as well as total production from a unit of land area, the winter annual should be maintained in the vegetative stage rather than allowing it to progress to maturity.

Mississippi researchers (*3*) sodseeded oats and ryegrass in bermudagrass sods in 8- and 16-inch drill spacings to study the effects of spacing on performance of winter annuals and subsequent perennial yields. The highest yielding treatment was oats drilled into sod at 8-inch intervals. The practice of drilling seed into sod results in more fall and winter production than did the conventional discing method. In general, summer perennial production was reduced in proportion to the degree to which the sod had been disturbed the previous fall.

Established perennial sods were seeded with subterranean clover, crimson clover, alfalfa, vetch, winter peas, oats, wheat, rye, and barley, as reported by Swain et al. (*10*). Rye and hairy vetch, when sodseeded into Midland bermudagrass, produced the earliest spring growth and outyielded barley, ryegrass, and wheat in that order.

EXPERIMENTAL PROCEDURE

Agronomic Procedure

In mid-October each year during 1977, 1978, 1979, and 1980, ½ acre plots of Pensacola bahiagrass and Alicia bermudagrass were subdivided, and one-third of each was sodseeded with Redland red clover. Another one-third was sodseeded with Gulf ryegrass, while the remaining one-third of each plot remained with the pure perennial sod. Prior to planting, the entire site was sprayed with Paraquat and burned to eliminate perennial forage residue. Fertilizer was surface-broadcast applied to the area to be sodseeded at the rate of 100 pounds per acre each of P_2O_5 and K_2O. Annuals were planted in 8-inch drills with a John Deere "Power Til" seeder at rates of 10 pounds per acre for red clover and 20 pounds per acre for ryegrass. The ryegrass received 150 pounds per acre of nitrogen in early December and again in mid-January each year.

The perennial alone and perennial-ryegrass sites received 72-216-216 pounds per acre of N, P_2O_5, and K_2O, respectively, in March each year. The perennial-clover plots received the same amounts of P_2O_5 and K_2O per acre, but no nitrogen was applied until May when perennial growth appeared in the mixtures. All treatments received 75 pounds of nitrogen per acre following each harvest during the summer months.

Annuals were harvested with a flail harvester at 2-week intervals until the perennials dominated the mixture, and thereafter, at 4-week intervals. Yield data were obtained by cutting four random strips, 5 X 12 feet, in each of the plots. The entire plot was harvested during the time when annuals constituted an appreciable portion of the forage mixtures; the total production was dried in a forced-air, thermostatically-controlled drier at 130°F

The dried forage was then chopped with a hammer mill to approximately inch lengths and stored for in vivo digestion trials.

In Vivo Digestibility Trials

Each of the chopped forages was fed to four sheep, which served as replicates, in conventional digestion trials consisting of a 9-day preliminary period followed by a 5-day total-fecal-collection period. The sheep were maintained in conventional digestion crates that permitted individual feeding (twice daily), weigh-backs (once daily), and total fecal collection. The chopped forages were sampled during each digestion trial, dried, and ground in a Wiley Mill to a 1-millimeter fineness for laboratory analyses.

Statistical Analyses

Statistical analyses of the data were conducted according to procedures described by Snedecor and Cochran (9). Yield and forage quality data are reported as clipping-date means. A regression analysis of each variable on clipping date was conducted using linear, quadratic, cubic, and quartic terms. The criterion for selection of a regression equation was significant at the .05 probability level for the highest order term. Regression analyses were based on data collected over a 4-year period (1978-1981) for sod-seeded plots and over a 3-year period (1979-1981) for pure Alicia bermudagrass or Pensacola bahiagrass stand.

RESULTS AND DISCUSSION

Dry Forage Yield Per Acre

Season-total dry forage yields averaged over the 4 years, in pounds per acre, for the stands were: Pensacola + ryegrass—10,870; Alicia + ryegrass—12,109; Pensacola + clover—10,151; Alicia + clover—10,242; Pensacola alone—8,578; and Alicia alone—10,365. The first harvest of ryegrass varied from January 15 in 1980 to April 2 in 1979, while clover was first harvested from April 6 to April 21 during the 4 years. The pure stands of perennials were first harvested from May 1 in 1979 to June 17 in 1980. The perennial + ryegrass and perennial + clover mixtures were harvested an average of 8.50 and 6.25 times per year, respectively, while the perennials in pure stands averaged 4.67 harvests per year. Delays in early spring growth of the perennials in pure swards limited the number of harvests and accounted for below expected season-total yields. The additional harvests of the perennials + ryegrass and perennials + clover mixtures accounted for the higher season-total yields.

Alicia yields, averaged over all treatments (alone or in combination with annuals), were 10.5 percent higher than similarly averaged Pensacola yields, but this difference was not significant at the .05 probability level. Alicia alone outyielded Pensacola alone by 20.7 percent and Alicia

ryegrass out-yielded Pensacola + ryegrass by 11.4 percent. Alicia + clover had practically the same yield as Pensacola + clover.

Ryegrass increased ($P < .05$) season-total yields in both Alicia and Pensacola stands. Season-total yields of Alicia were increased 16.8 percent by the incorporation of ryegrass, and Pensacola yields were increased 26.6 percent.

The average dry matter yield of Alicia + clover was almost identical to that of Alicia alone, but the incorporation of red clover in Pensacola sod increased season-total yield 18.2 percent over Pensacola alone.

Forage productivity was extended approximately 75 days with the addition of ryegrass and approximately 30 days by addition of red clover to perennial sods.

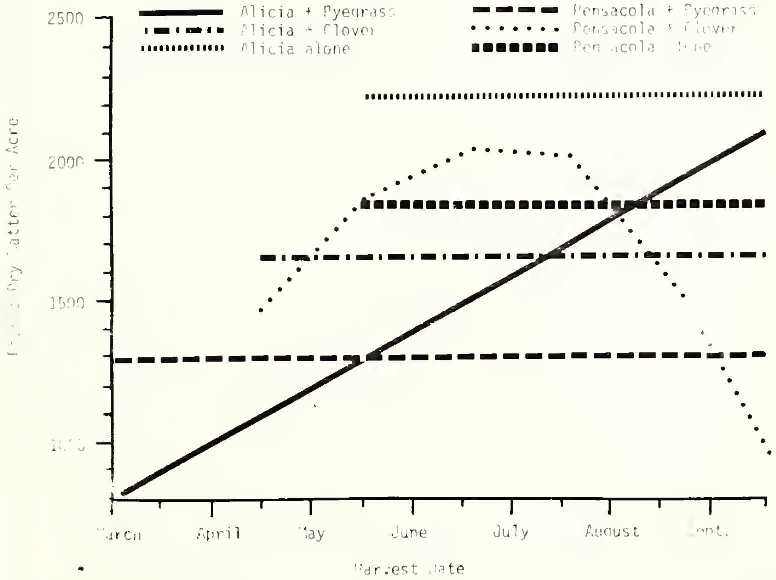

Figure 1.—Seasonal distribution of predicted dry forage yield of Pensacola bahiagrass and Alicia bermudagrass in pure stands and in mixtures of sodseeded red clover or ryegrass, 1978-81.

Seasonal distribution of dry-forage production is shown in Figure 1. There were no seasonal trends in yield distribution of Alicia alone, Pensacola alone, Pensacola + ryegrass, or Alicia + clover. There was a linear increase in dry forage yield of Alicia + ryegrass as the season advanced. The Pensacola + clover mixture produced its highest yield in June and then decreased through September. Both Alicia alone and Alicia + ryegrass produced significantly ($P < .05$) more dry forage than Pensacola + ryegrass late in the season (after mid-July). Pensacola + ryegrass was also lower in yield than Pensacola + clover in July but not significantly different in August and September.

Botanical Composition

Since annual grasses and legumes are generally higher in quality th perennial grasses, their contribution to the mixture is advantageous in improving forage quality.

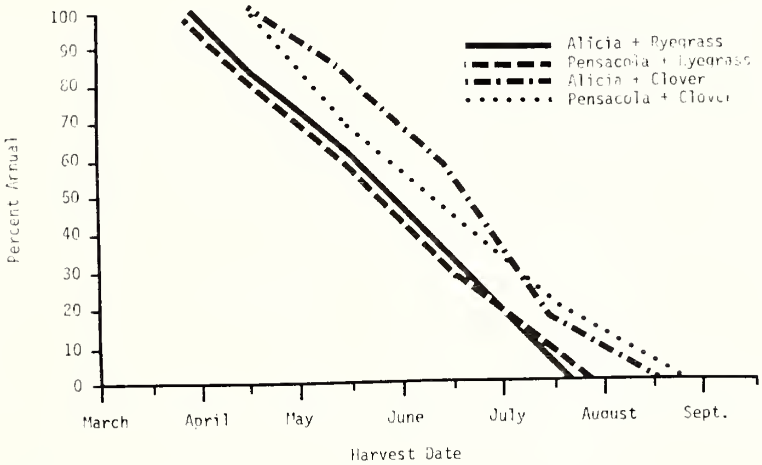

Figure 2.—Predicted percent annual forage in mixtures of Pensacola bahiagrass and Alicia bermudagrass sodseeded with red clover or ryegrass, 1978-81.

Ryegrass constituted 100 percent of the yield harvested through April 1 (Figure 2). There was a decrease in percentage ryegrass in mixtures through July 25; ryegrass was absent in all harvests after July 25.

Clover represented 100 percent of mixtures harvested through April 15. Thereafter, the percentage of clover decreased through August 15, with no clover present in the September harvest.

There was approximately 10 percent more clover in the Alicia + clover mixture from May 15 through June 15 than in the Pensacola + clover mixture. However, these differences were not statistically significant. Clover contributed from 10 to 15 percent more to the botanical composition of mixtures than ryegrass from April 15 to about August 15.

Nutrient Production Per Acre

Digestible dry matter (DDM) production (Figure 3) followed a trend very similar to that of dry forage yield. Season-total DDM value, in pounds per acre, for the stands were: Pensacola + ryegrass—6,856; Alicia + ryegrass—7,455; Pensacola + clover—6,237; Alicia + clover—5,695. Pensacola alone—4,860; and Alicia alone—5,476. There was no seasonal trend in DDM production of Alicia alone, Pensacola alone, Alicia + clover, or Pensacola + ryegrass. A linear increase occurred in DDM production with Alicia + ryegrass as the season advanced. The Pensacol

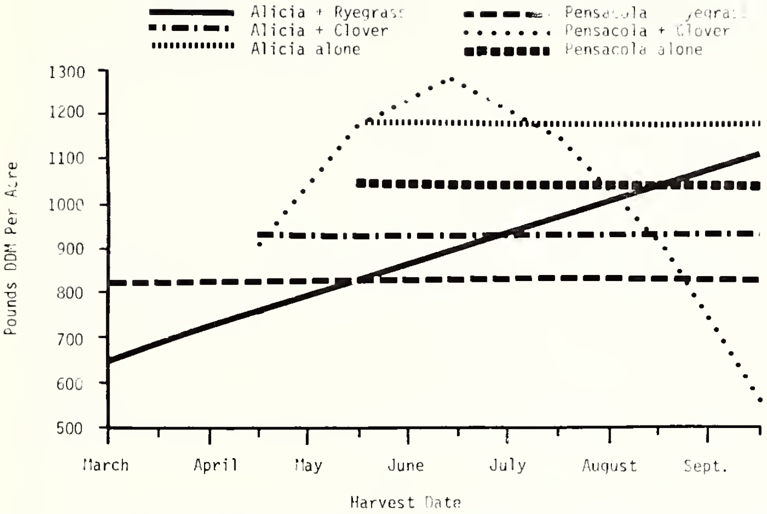

Figure 3.—Seasonal distribution of predicted digestible dry matter per acre produced by Pensacola bahiagrass and Alicia bermudagrass in pure stands and in mixtures sodseeded with red clover or ryegrass, 1978-81.

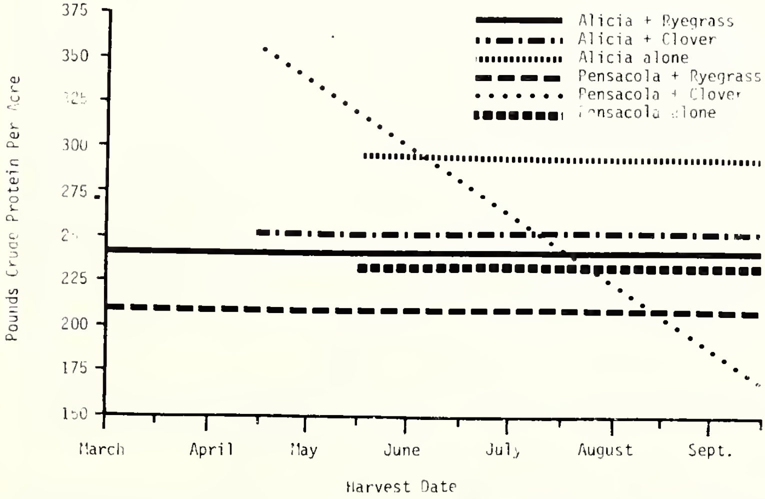

Figure 4.—Seasonal distribution of predicted crude protein per acre produced by Pensacola bahiagrass and Alicia bermudagrass in pure stands and in mixture sodseeded with red clover or ryegrass, 1978-81.

+ clover mixture produced its highest DDM per acre in June and then decreased through September.

Crude protein (CP) production levels, in pounds per acre, for the different stands were: Alicia + ryegrass—2,033; Pensacola + ryegrass—1,776; Alicia + clover—1,642; Pensacola + clover -1,659; Alicia alone 1,776; Alicia + clover—1,642; Pensacola + clover—1,659; Alicia alone—1,354; and Pensacola alone—1,091. Only one mixture, Pensacola + clover, was affected by season, with a linear decrease in CP per acre from April through September (Figure 4). Pensacola + clover produced significantly ($P<.05$) more CP per acre than Pensacola + ryegrass through the June harvest. The incident of higher forage quality and additional harvests from ryegrass and clover in stands accounted for the higher season-total nutrient yields of mixtures.

STRUCTURAL CARBOHYDRATES

Cell Wall Constituents

Cell wall constituents (CWC) include the total fibrous fraction of forage, that portion of plant material acted on by rumen microfloria, and consist of acid detergent fiber (ADF) and hemicellulose. The ADF is further subdivided into cellulose and lignin. Cell wall constituents make up the major

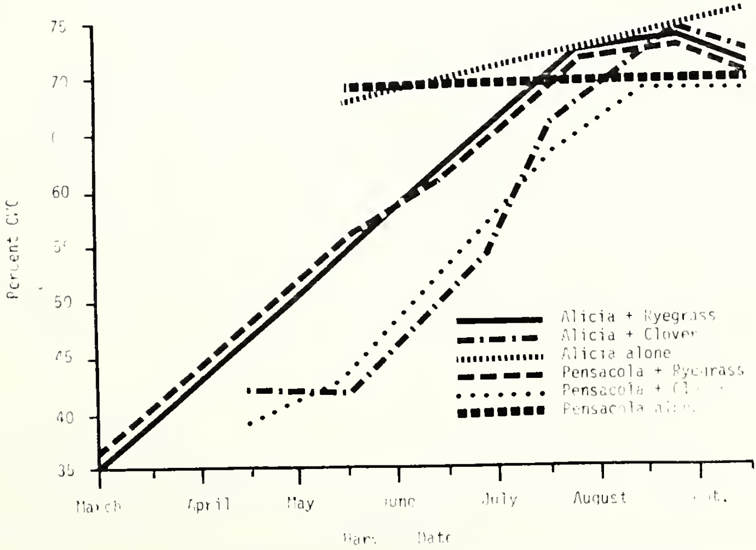

Figure 5.—Predicted cell wall constituents content of Pensacola bahiagrass and Alicia bermudagrass in pure stands and in mixtures sodseeded with red clover or ryegrass, 1978-81.

part of a perennial plant cell, and generally the higher the CWC content the lower the quality of that forage.

Cell wall constituent values of the forages, plotted throughout the season appear in Figure 5; percentages ranged from 35.0 in March, when ryegrass was predominate in the mixture, to 72.0 in August, when perennials dominated the stands. The presence of ryegrass or clover in stands during June and July resulted in significantly lower ($P<.05$) CWC percentages than in forage from perennials alone.

No significant differences were observed in CWC percentages between Alicia + ryegrass and Pensacola + ryegrass mixtures at any harvest date during the season. The perennial + clover mixtures exhibited significantly lower ($P<.05$) CWC content than perennial + ryegrass mixtures through mid-July, with no differences in August and September when only the perennials were present. Cell wall constituent percentage of Pensacola alone was not affected by date of harvest, while that of forage from a pure stand of Alicia increased from May through September. There was no significant difference in CWC content among treatments from mid-July through mid-September, when perennials predominated.

Acid Detergent Fiber

Acid detergent fiber (ADF) is the most realistic measure of forage fiber that may be digested by ruminants. Acid detergent fiber includes lignin, a component only partially extracted in the crude fiber analysis. Since ADF is a part of CWC, the seasonal trend of ADF is very similar to that of CWC.

Acid detergent fiber percentages of perennial + ryegrass mixtures ranged from 22.0 in March to 35.0 in September (Figure 6). Perennial + clover mixtures exhibited lower ADF values than perennial + ryegrass mixtures. Acid detergent fiber percentages of Pensacola + clover mixtures were numerically higher than those of Alicia + clover mixtures, although not statistically significant. Acid detergent fiber content of Alicia alone was not affected by harvest date, with a season average of 34.0 percent. ADF of Pensacola alone increased as the season advanced from May through September. There were no significant differences in ADF percentages among treatments from August through September, when only perennials were present.

Hemicellulose

Hemicellulose content in forage is regarded as the difference between CWC and ADF and is generally more digestible than cellulose. It is composed of a mixture of polymers, which may have different digestion coefficients within the same forage. Hemicellulose content of Alicia and Pensacola forages in pure stands were not affected by harvest date, with season averages of 36.2 and 34.4 percent, respectively (Figure 7). Hemicellulose percentages of the perennial + ryegrass and perennial +

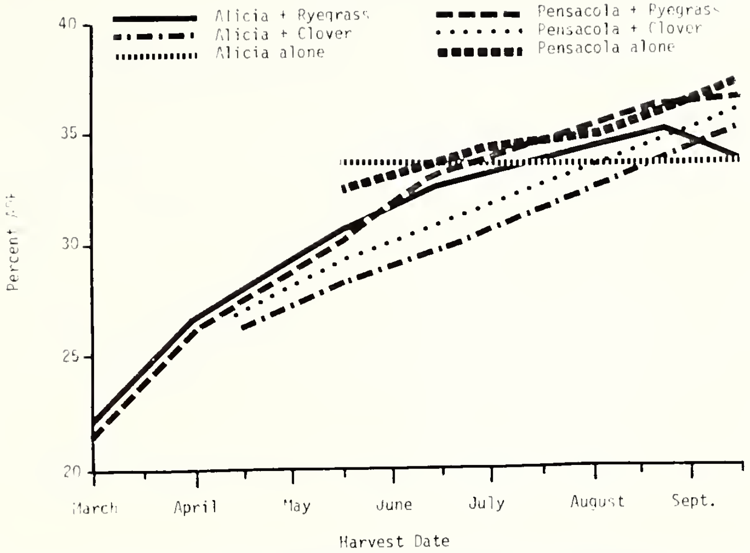

Figure 6.—Predicted acid detergent fiber content of Pensacola babiagrass and Alicia bermudagrass in pure stands and in mixtures sodseeded with red clover or ryegrass, 1978-81.

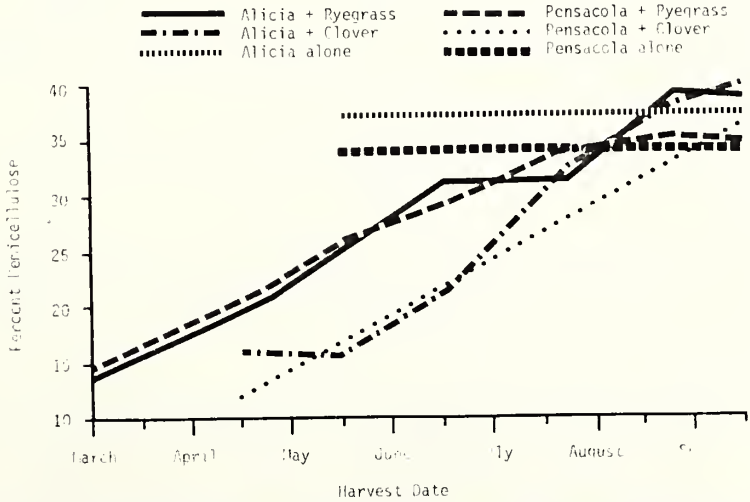

Figure 7.—Predicted hemicellulose content of Pensacola bahiagrass and Alicia bermudagrass in pure stands and in mixtures sodseeded with red clover or ryegrass, 1978-81.

clover mixtures increased significantly ($P<.05$) as the season advanced. There was no significant difference between hemicellulose content of Alicia + ryegrass and Pensacola + ryegrass mixtures at any harvest date. Mixtures including ryegrass were significantly lower ($P<.05$) in hemicellulose than perennials alone until late June, and mixtures including clover were lower than the perennials alone until late July. Perennial + clover mixtures were significantly lower ($P<.05$) in hemicellulose than mixtures containing ryegrass until July 1. No significant differences were found in hemicellulose percentages among treatments in August and September

Cellulose

There were significant ($P<.05$) increases in cellulose content of perennials + ryegrass and perennials + clover as the season advanced through August (Figure 8). Cellulose percentages of Alicia and Pensacola in pure

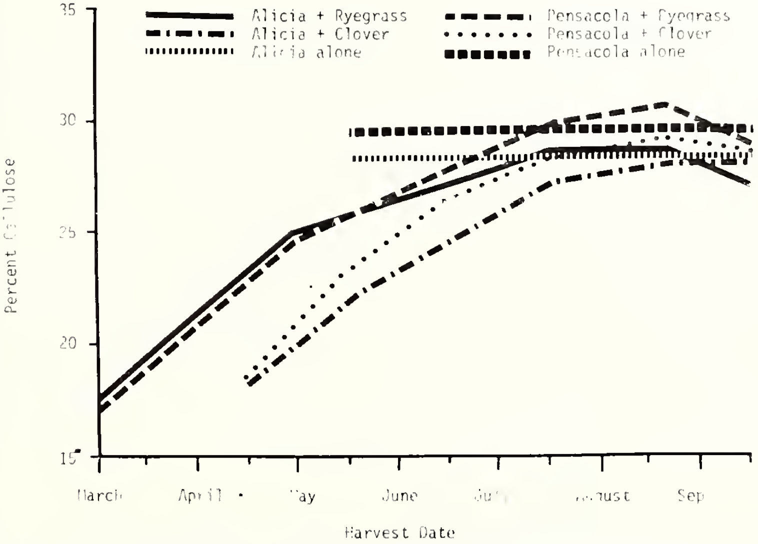

Figure 8.—Predicted cellulose content of Pensacola bahiagrass and Alicia bermudagrass in pure stands and in mixtures when sodseeded with red clover and ryegrass, 1978-81.

stands were not affected by harvest date, with season averages of 27.5 and 28.5, respectively. Cellulose content ranged from 17.0 percent in March for perennials + ryegrass to 30.0 percent in August for Pensacola + ryegrass. Since clover is lower in cellulose than ryegrass and persisted in mixtures longer than ryegrass, perennial + clover mixtures exhibited significantly lower ($P<.05$) cellulose percentages than perennial + ryegrass mixtures from mid-April to June. Pensacola + clover mixtures

exhibited consistently non-significantly higher cellulose content than Alicia + clover mixtures. Cellulose percentages did not differ ($P < .05$) among treatments after July when perennials dominated the mixtures.

Acid-Insoluble Lignin

Lignin is considered completely indigestible and a true "anti-quality" factor. Acid-insoluble lignin (AIL) content of Alicia + ryegrass increased from 1.75 percent in March to 5.00 percent in July (Figure 9). There was no

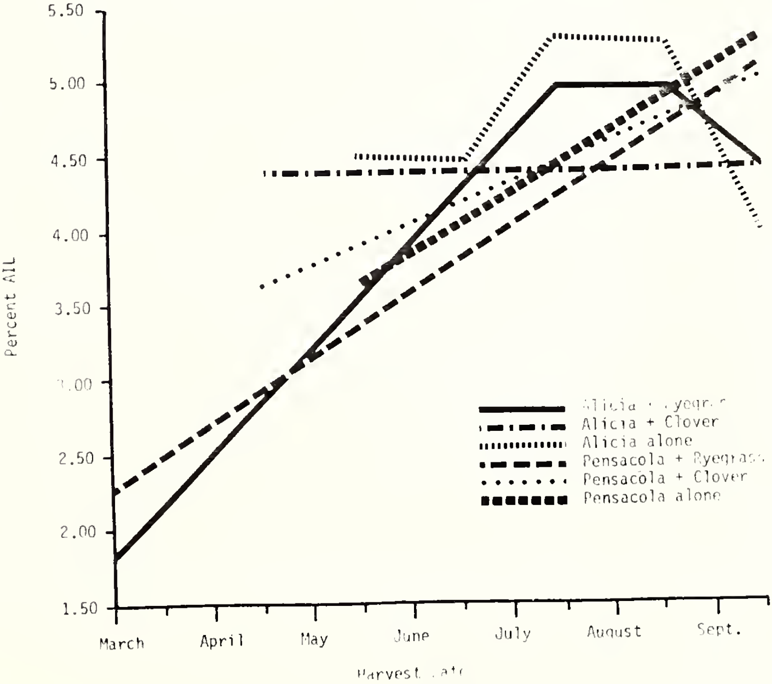

Figure 9.—Predicted acid insoluble lignin content of Pensacola bahiagrass and Alicia bermudagrass in pure stands and in mixtures sodseeded with red clover or ryegrass, 1978-81.

significant difference in AIL content of Alicia + ryegrass and Pensacola + ryegrass mixtures at any harvest date. However, AIL of Alicia + ryegrass was numerically higher than that of the Pensacola + ryegrass mixtures in June, July, and August. There was a linear increase in AIL content of Pensacola + clover as the season advanced. The AIL content of Alicia + clover was not affected by harvest date, with an average of 4.45 percent. Acid insoluble lignin content of Pensacola in pure stand increased linearly from 3.60 percent in early-May to 5.20 percent in mid-September

AIL content of Alicia alone was highest in late July and early August. Alicia alone exhibited significantly higher ($P<.05$) AIL percentages than Alicia + clover from mid-July to mid-August. There was no other significant difference in AIL content among treatments from mid-June through mid-September.

Crude Protein

Crude protein (CP) content of forages has long been recognized as an indicator of quality in rations for ruminants. Crude protein level of forage ranging from 15.6 to 18.7 percent, dry matter basis, is considered adequate to meet the protein needs of a beef cow with calf. As noted in Figure 10, the minimal protein requirements were met only while annuals contributed to production. Sharp decreases occurred in CP content of forage as annuals decreased in the mixtures. Clover maintained high CP content of mixtures later into the season than did ryegrass. Crude protein percentages of perennials + clover were significantly ($P<.05$) higher than those of perennials + ryegrass from early May through late June. There were no significant differences in CP content of either perennial + ryegrass mixtures or perennial + clover mixtures at any harvest date. Pure stands of Alicia and Pensacola did not differ significantly in CP content, with season averages of 14.2 and 13.4 percent, respectively. There were no significant differences in CP percentages among treatments from July through September.

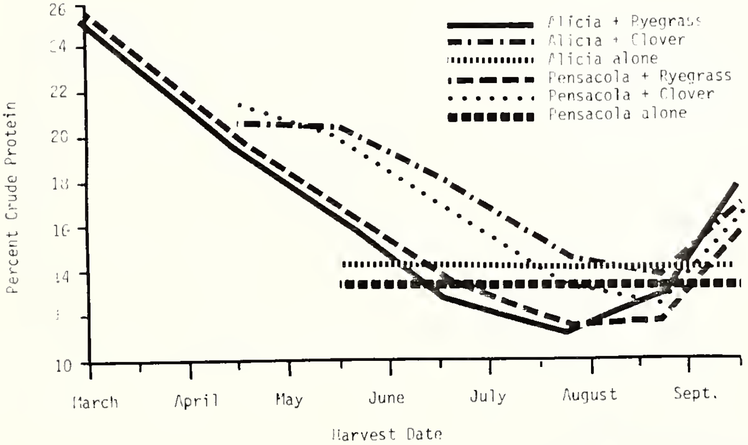

Figure 10.—Predicted crude protein content of Pensacola bahiagrass and Alicia bermudagrass in pure stands and in mixtures sodseeded with red clover or ryegrass, 1978-81.

In Vitro Digestible Dry Matter

In vitro digestible dry matter (IVDDM) is generally regarded as a relative or approximate measure of the nutritional value of a forage. Results reported in other studies (*1*, *6*, *7*) have shown a high positive correlation between IVDDM (Test Tube) values and DDM (animal) values for forages.

The IVDDM values reported in Figure 11 represent apparent DDM and were calculated from the formula: Apparent DDM = 15.1 + 5416X where X is the test tube digestion value (*7*).

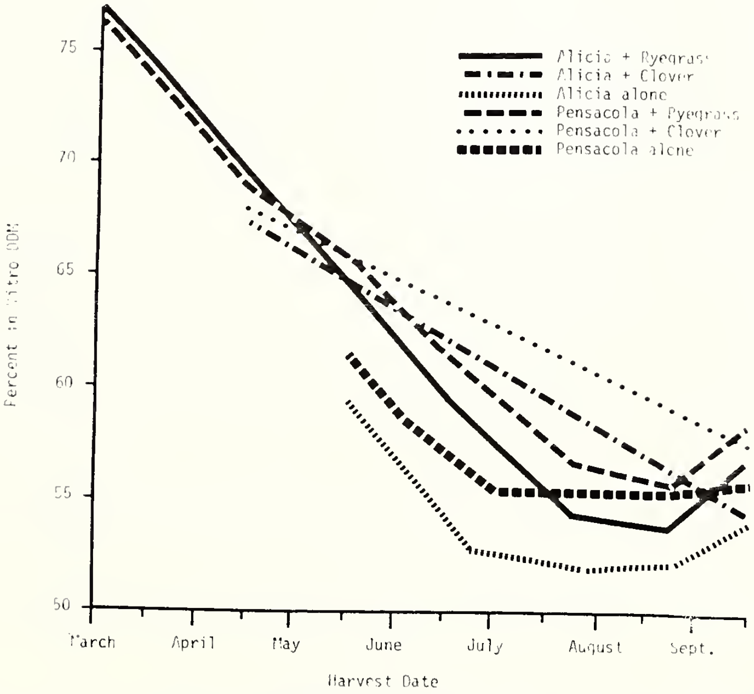

Figure 11.—Predicted in vitro digestible dry matter content of Pensacola bahiagrass and Alicia bermudagrass in pure stands and in mixtures sodseeded with red clover or ryegrass, 1978-81.

No significant differences occurred in IVDDM between Pensacola + ryegrass and Alicia + ryegrass at any harvest date. However IVDDM percentage decreased sharply from March through August, with only a slight increase at the September harvest. IVDDM ranged from 77 percent in March, when ryegrass represented 100 percent of the mixture, to 55 percent in August when only the perennials were present. There were linear decreases in IVDDM of perennial + clover mixtures, from 67 percent in mid-April to 56 percent in September. There was no significant difference in IVDDM of Alicia + clover and Pensacola + clover mixtures, but IVDDM of Pensacola + clover was consistently higher numerically.

Pensacola and Alicia in pure stands exhibited sharp decreases in IVDDM content from mid-May through late June, with no significant changes during the remainder of the season. IVDDM values for the pure stand of Pensacola were consistently higher than those of Alicia alone, although not statistically significant.

Mixtures of perennial + clover exhibited significantly ($P<.05$) higher IVDDM values than either perennial alone until mid-July. No significant differences were observed among treatments during August and September.

Component Digestibility

During the 4-year period individual harvests of four perennial + ryegrass mixtures and thirteen perennial + clover mixtures were selected, based on presence of annuals in the harvest, to be evaluated in *in vivo* digestion trials. Harvest dates for the perennial + ryegrass mixtures ranged from May 1 to June 25, while perennial + clover mixtures were harvested from April 6 to August 24.

Table 1. Component digestibility[1] of Pensacola bahiagrass and Alicia bermudagrass sodseeded with red clover or ryegrass, 1978-81

		Digestibility					
Treatment	Harvests[2]	DDM[3]	CWC[4]	HC[5]	ADF[6]	Cellulose	CP[7]
		Percent					
Alicia + Ryegrass	4	56.7	56.0	61.2	54.5	67.3	60.0
Pensacola + Ryegrass	4	62.5	60.7	70.2	54.8	68.6	59.2
Alicia + Clover	13	61.7	58.6	70.0	51.3	67.4	68.9
Pensacola + Clover	13	62.8	60.8	75.4	53.[illegible]	70.5	64.8

[1] Digestibility values based on laboratory analyses of forage consumed and fecal excretion of four sheep per treatment.

[2] Number of individual harvests used in digestion trials during the four-year period

[3] In vivo digestible dry matter.

[4] Cell wall constituents

[5] Hemicellulose.

[6] Acid-detergent fiber.

[7] Crude protein

Mean digestion coefficients, over all harvests, for dry matter, structural carbohydrates (CWC, ADF, hemicellulose, cellulose), and CP are presented in Table 1. Mixtures containing Pensacola exhibited consistently higher digestibility for all structural carbohydrates and dry matter than those containing Alicia. However, digestibility of CP was higher in mixtures containing Alicia; these differences were observed in both ryegrass and clover mixtures. With the exception of ADF, structural carbohydrates digestion coefficients tended to be higher for mixtures containing clover; these differences would be of no practical significance in animal performance.

SUMMARY AND CONCLUSIONS

Both Pensacola bahiagrass and Alicia bermudagrass were sodseeded with red clover or ryegrass under field conditions over a 4-year period and evaluated for forage yield, distribution of yield, chemical composition, and digestibility. Highest season-total yields were obtained by sodseeding Alicia with ryegrass. Alicia, averaged over all treatments, produced 10.5 percent more DM than Pensacola treatments. Alicia yields were increased 16.8 percent by the incorporation of ryegrass, while Pensacola yields were increased 26.6 percent. Pensacola plot yields were increased 18.2 percent with the incorporation of clover, while Alicia plot yields were unchanged.

Forage productivity was extended approximately 75 days by sodseeding ryegrass and approximately 30 days by sodseeding clover.

Ryegrass and clover accounted for 100 percent of forage mixtures at the initial harvest, and then decreased as the season advanced. Clover persisted in mixtures later into the season than ryegrass. Forage quality declined as annuals decreased in mixtures.

The incorporation of ryegrass and clover resulted in lower structural carbohydrates (CWC, ADF, hemicellulose, and cellulose) percentages early in the season, but these components increased as annuals decreased in mixtures.

Crude protein percentage was reduced as annuals decreased in mixtures. Clover mixtures contributed to CP content in mixtures later into the season than ryegrass mixtures. There was no difference in CP content of Pensacola and Alicia forages in pure stands.

Digestibility of mixtures declined as annuals decreased in the stand. The presence of clover improved digestibility further into the season than did ryegrass.

Digestibility of structural carbohydrates in mixtures containing Pensacola was consistently higher than those of Alicia. Crude protein digestibility was highest in mixtures containing Alicia.

These data reveal that Pensacola bahiagrass and Alicia bermudagrass can be successfully sodseeded with ryegrass or red clover, resulting in extended forage productivity and improved forage quality.

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Appendix

Appendix Table A.—Examples of the coefficients for equations used in generating the predicted values displayed in Figures 1 to 11.

1. *Pounds Dry Matter per Acre (Y) for Alicia + Ryegrass* would be predicted from the equation
   $\hat{Y} = 443 + 6.54\,D$
   Where Y is the predicted pounds of dry matter per acre on Julian date D.
   The predicted DM yield for a harvest on Julian date 200 (July 17) would be:
   $\hat{Y} = 443 + 6.54\,(200)$,
   or $\hat{Y} = 1751$ pounds dry matter per acre.

2. *Pounds Dry Matter per Acre (Y) for Alicia + Clover* would be predicted as $\hat{Y} = 2221$ for any harvest date. This value is the average yield for all harvest dates.
3. Percent Annual (Y) for Alicia + Ryegrass would be predicted from the equation: $Y = 66.8 + 1.69D$ $0.0186D^2 + 0.0000427D^3$. Consequently, the predicted percent annual in the Alicia Ryegrass mixture on Julian date 150 (May 29) would be:
   $\hat{Y} = 66.8 + 1.69\,(150) - 0.0186\,(150)^2 + 0.0000427\,(150)^3$,
   or $\hat{Y} = 45.9$ percent annual in the mixture.

When there is not a statistically significant ($P < .05$) seasonal trend, the mean of the variable is listed under the "intercept" column. Prediction equations are constructed from the coefficients.

Appendix Table B—Coefficients in Prediction Equations used for Figures 1 [illegible]

Variable	Treatment[a]	CV[b]	R^2[c]	Intercept[d]	Coefficients of Equations		
					Julian date (D)	D^2	D^3
Pounds Dry Matter Per Acre (Figure 1)	1	53	.29	443	6.54		
	2	46		1639			
	3	56		2221			
	4	60		1279			
	5	45	.22	-2310	50.0	-0.143	
	6	56		1840			
Percent Annual (Figure 2)	1	37	.86	66.8	1.69	-0.0186	0.0000427
	2	22	.95	-145.4	5.35	-0.0363	0.0000688
	4	36	.87	68.8	1.65	-0.0185	0.0000431
	5	23	.95	238.9	-1.63	0.00269	
Pounds DDM Per Acre (Figure 3)	1	50	.16	483	2.63		
	2	43		911			
	3	53		1173			
	4	54		807			
	5	42	.26	-874	25.57	-0.0771	
	6	53		1041			
Pounds Crude Protein Per Acre (Figure 4)	1	63		239			
	2	48		263			
	3	51		290			
	4	66		209			
	5	45	.25	482	1.39		
	6	43		234			
Percent CWC (Figure 5)	1	9	.90	36.9	-0.207	0.00389	-0.00000996
	2	13	.78	208.3	-3.27	0.0200	-0.0000364
	3	5	.30	59.5	0.0533		
	4	8	.90	35.5	-0.151	0.00334	-0.00000863
	5	12	.78	140.4	-2.10	0.0137	-0.0000256
	6	4		69.0			
Percent ADF (Figure 6)	1	10	.75	11.3	0.204	-0.000457	
	2	14	.33	20.8	0.0543		
	3	8		33.6			
	4	11	.75	12.7	0.177	-0.000330	
	5	14	.37	21.1	0.0582		
	6	7	.31	27.6	0.0360		
Percent Hemicellulose (Figure 7)	1	12	.90	20.6	-0.251	0.00303	-0.00000691
	2	20	80	135.2	2.31	0.0139	-0.0000246
	3	8		36.9			
	4	13	.87	17.4	-0.154	0.00224	0.0000005[illegible]
	5	23	.71	-3.8	0.152		
	6	8		34.2			

(Continued)

Table B—Coefficients in Prediction Equations used for Figures 1 to 11. (Continued)

				Coefficients of Equations			
Variable	Treatment[a]	CV[b]	R^2[c]	Intercept[d]	Julian date (D)	D^2	D^3
Percent Cellulose (Figure 8)	1	8	.84	14.2	0.0405	0.000557	-0.00000199
	2	10	.73	-0.7	0.226	-0.000445	
	3	7		28.1			
	4	10	.82	15.9	-0.0298	0.00116	-0.00000328
	5	10	.75	-9.2	0.341	-0.000755	
	6	8		29.1			
Percent AIL (Figure 9)	1	23	.69	2.98	-0.0454	0.000538	-0.00000132
	2	24		4.38			
	3	17	.50	40.73	-0.642	0.00362	-0.00000654
	4	22	.67	1.24	0.0146		
	5	25	.17	2.76	0.00852		
	6	9	.65	1.97	0.0118		
Percent Crude Protein (Figure 10)	1	25	.54	20.5	0.191	-0.00257	0.00000694
	2	19	.42	-31.9	1.05	-0.00665	0.00000127
	3	25		14.0			
	4	24	.57	18.6	0.222	-0.00264	0.00000667
	5	15	.65	-26.1	0.990	-0.00652	0.0000128
	6	21		13.6			
Percent IVDDM (Figure 11)	1	5	.88	73.8	0.232	-0.00332	0.00000840
	2	9	.40	75.7	-0.0812		
	3	4	.60	101.8	0.469	0.00111	
	4	6	.81	77.0	0.120	[illegible]	[illegible]
	5	8	.37	75.1	-0.0691		
	6	3	.82	220.1	-2.31	0.0107	-0.0000162

[a] The treatments are numbered as follows:

Treatment 1	Alicia + ryegrass
Treatment 2	Alicia + clover
Treatment 3	Alicia alone
Treatment 4	Pensacola + ryegrass
Treatment 5	Pensacola + clover
Treatment 6	Pensacola alone

[b] Coefficient of variation in percent.

[c] Coefficient of determination.

[d] For no significant ($P < .05$) seasonal trend, the intercept is the average for all harvests.

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SOYBEAN INOCULATION IN LOUISIANA

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Louisiana Agricultural Experiment Station, Doyle Chambers, Director
Louisiana State University Agricultural Center, Alvin C. Harper, Chancellor

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Soybean Inoculation In Louisiana

Edward P. Dunigan,[1] Patrick K. Bollich,[1]
Frederick C. Zaunbrecher,[1] Patrick M. Hicks[1]
and Walter C. Morrison[2]

The question of whether or not to inoculate soybean seeds prior to planting has plagued both growers and researchers in recent years. Several reports in the scientific literature (Johnson et al., 1965; Caldwell and Vest, 1970; Ham et al., 1971; Boonkerd et al., 1978) have indicated very low recovery of the inoculant-bacteria from soybean nodules. Weaver and Fredericks (1974a) found that when soybeans were grown in Iowa soils containing 1,000 or more *Rhizobium japonicum* per gram, the roots were not likely to be extensively nodulated by the inoculant rhizobia when it was applied at normal rates of less than 10,000 rhizobia per seed. In a companion study (1974b), they predicted that if the inoculant-rhizobia were to form 50 percent of the nodules, an inoculation rate of at least 1,000 times the soil population per gram would have to be used. At the same time, Kvien et al. (1978) noted in greenhouse and field experiments that both nitrogen fixation and seed yield could be increased through proper *Rhizobium* strain selection. Researchers in Arkansas (Wolf and Nester, 1980) have reaffirmed that use of a good inoculant may be necessary when soybeans are grown in fields where the nodulating rhizobia are not present. However, most researchers in the South are of the opinion that if soybeans were well nodulated in one growing season, they will be nodulated in that same field in subsequent years. Some recommend inoculation every 4 to 5 years.

When one sifts through the conflicting reports, it is apparent that this lack of general agreement would not lend itself well to making an inoculation recommendation to Louisiana soybean growers. Inoculation problems in Louisiana are unique to the state and cannot be solved by research reports from states in the Midwest or even other southern states. For this reason a study was initiated in the Department of Agronomy of the Louisiana Agricultural Experiment Station in 1979 to investigate the effects of inoculation of seed on nitrogen fixation and seed yield of

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soybeans. Four year's outfield data were gathered from cooperating Louisiana farmers located throughout the state. Tests were conducted on both first-year soybean land and in fields previously cropped to soybeans.

Test Procedures

In 1979, a letter was sent to most Louisiana Cooperative Extension Service parish agents located in the soybean growing areas of Louisiana asking them to aid in locating farmers who would cooperate in a soybean inoculation test. Eighteen growers in 15 parishes agreed to cooperate. In 1980, 10 outfield tests were planned but only four were successfully carried to completion. In 1981, 13 tests were conducted at nine outfield locations. In 1982, three test sites were used. These test areas are shown in Figure 1.

All participating growers agreed to plant both inoculated and uninoculated soybean seed within one field. Almost all of the participants already used an inoculation program so the usual procedure was to plant several planter box widths of uninoculated seed when first beginning to plant the test field. This usually varied from 12 rows to 50 or more rows of uninoculated seed. Usually it consisted of one planter box (several bushels) of seed. These strips extended the entire distance of the field regardless of length. Once the uninoculated seed were planted, the hopper box was filled with inoculated seed of the same cultivar and planting was resumed. The dividing row was plainly marked for future reference. In one exception, one grower indicated he was not going to inoculate his seed. Inoculum was provided to him and he reversed the previous procedure, first inoculating and then continuing with uninoculated seed. No attempts were made to influence the growers with respect to brand or type of inoculant used. All inoculants were applied by the farmer and all subsequent management practices were carried out by him according to his own plans.

In 1979, nodulation and nitrogen fixation were checked once at all locations. This was done as close to flowering as possible. In 1980, 1981, and 1982, these tests were conducted twice at each location, once at flowering and again at early pod fill. Ten plant samples were carefully excavated within a large area of both inoculated and uninoculated areas. Large distances were maintained between the two sampling areas. Sampling was never conducted on the several outside rows so as not to encounter border effects. Nitrogen fixation rates were determined by the Acetylene Reduction technique right in the field (Hardy et al., 1968). This is a test in which acetylene (C_2H_2) is preferentially fixed to ethylene (C_2H_4) by the nitrogen-fixing system of the plant. Although it is not possible to express these values as nitrogen fixed without the use of a second test ($^{15}N_2$ reduction), it is a valuable tool to compare rates of

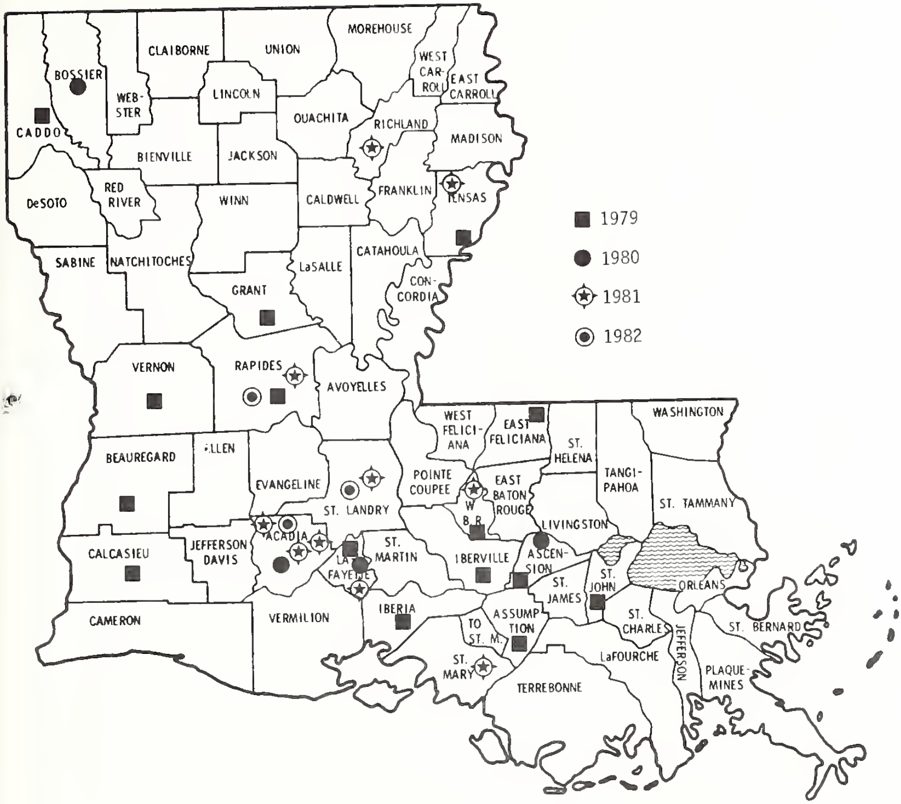

Fig. 1.—Location of soybean inoculation trials, 1979-82.

fixation between treatments. The roots were removed to the laboratory and nodule numbers and nodule dry weight were determined. Ethylene was determined with a Perkin-Elmer gas chromatograph. Rates of reduction were then calculated from these data.

Seed yields were obtained when the farmer was ready to harvest the test field. Just prior to harvesting, 10 yield strips were measured out within the center of each test area and marked with brightly colored flags. In most instances, each yield strip was 25 feet in length. In a few tests, 50-foot harvest strips were used. These lengths were dictated by the number of rows that the farmer's combine would accommodate. When more than four rows were harvested, it was difficult to hold the test sack in place for more than 25 feet. The actual harvesting was performed by two people located inside the combine box. The combine was run through 50 to 100 yards of row to allow a full flow of seed into the catch box. One person then indicated the start and finish of each test strip while the other held a large sack under the delivery tube of the combine. Strips were left between each yield strip to allow for switching to the next sack. Seeds continued to enter the box during this time as harvesting was still continuing on the test rows.

Seed weights were taken immediately in the field. All seeds, with the exception of a small moisture sample, were then left in the combine. Yields were determined at 13 percent moisture content. All data pertaining to nodulation and nitrogen fixation were analyzed by a completely randomized design for each farmer's field. For data analysis, the SAS analysis of variance program was used and computations were done through the Systems Network Computer Center at LSU. Yield data were handled by a more restrictive test. Yield values for new and previously cropped soybean land were compared using an analysis of variance for a randomized block design with fields as blocks. An estimate of error variance was calculated. Using this value, yield differences from individual fields were tested for significance and confidence intervals for mean yield differences were obtained.

All soil properties were determined by the LSU Soil Testing Laboratory.

Results

Test sites for the 3-year soybean inoculation study are shown in Figure 1. Although some growers cooperated in more than 1 year, no two tests were ever conducted on the same field. The locations indicate that, during the 3-year period, tests were conducted in most of the soybean growing areas of the state.

A complete list of all of the cooperators, arranged alphabetically by parish, is shown in Table 1. Data on the brand of inoculant, soybean seed variety, and row spacings employed in the tests, plus some soil chemical and physical properties, are also listed. Each location is also classified by whether or not it had a previous history of soybean growth. These data indicate that the tests encompassed diverse choices within each column of the table. Two different types of seed inoculant were employed. One was a peat-base inoculant, i.e. Nitragin or Rudy Patrick, while the second type was an oily liquid, Setre or Kalo's Triple Noctin. Forrest was the most popular choice of seed varieties and it was used at 13 of the locations during the 3-year period. Davis was used as the test variety at five locations, while Bragg, Ransom, and the Terra Vigs were each used at four different sites. Centennial and Tracy were the choices at three locations, and Bossier, DPL 345 and 506, Hood, Lee, and SRF 450 were each used at one location.

Row spacings varied from broadcast and closely drilled rows to the more standard 30- to 40-inch row spacings.

One objective of the study was to determine the response of seed inoculation on land that had no previous history of soybean growth (new soybean land). This would be the land that would be most likely to have no indigenous populations of *Rhizobium japonicum* and therefore would be most apt to respond to seed inoculation with the nodulating bacteria. Seventeen of the tests were put on land planted to soybeans for the first time, while 26 of the sites had a previous history of soybean growth.

Soil texture varied from light-textured soil, very fine sandy loam (vfsl), to heavy clay (c) soils. Most of the tests were on medium-textured, silt loam (sil) soils to heavy textured, silty clay loam (sicl) or clay (c) soils.

The pH values encountered ranged from 5.0 to 7.6. Most soil pH values were in the pH 6 to 7 range. This is a desirable pH range with respect to nodulation and growth of soybeans. Alexander (1977) indicated that rhizobial infection of leguminous root systems is adversely affected by pH values below 5.0. None of the pH values for the test soils fell below this value, although two locations did have pH values of 5.0.

Organic matter percent varied from 0.39 percent to 4.14 percent. The maximum value was considered unusually high for Louisiana soils and most of the locations had organic matter contents in the range of 1 percent to 2 percent.

Phosphorus values varied from 10 to 277 parts per million (ppm), potassium ranged from 30 to 473 ppm, and calcium and magnesium values ranged from low values of 261 and 32 ppm, respectively, to in excess of the test limits, 4,000 and 1,000 ppm, respectively.

Nodulation and N_2 fixation values, measured in terms of reduced acetylene, are summarized in Table 2. The acetylene reduction technique is an accepted standard method used to measure rates of N_2 fixation. When nitrogen is fixed by a soybean plant, N_2 reacts with H_2 within the nodule and NH_3 and then amino acids are quickly formed:

$$N_2 + 3H_2 \xrightarrow[\text{soybean roots}]{\text{nodulated}} NH_3 \longrightarrow \text{amino acids.}$$

It is very difficult to test this rate of fixation in the field. However, it is quite easy to shut this system off with acetylene. The plant can then reduce this acetylene to ethylene, which can be measured easily in the field.

$$HC{\equiv}CH + H_2 \xrightarrow[\text{soybean roots}]{\text{nodulated}} H_2C{=}CH_2$$

Although the rates of ethylene to reduced nitrogen usually are not found to be in a 3:1 ratio as it would appear from the equations, the test still allows quantitative comparisons to be made between different treatments.

Table 1. — Summary of locations, growers, and physical and chemical properties of soils used in soybean inoculation tests, 1979-82

Parish	Nearest town	Cooperating grower	Inoculent brand	Seed variety	Row spacing (inches)	New soybean land	Soil texture	pH	Organic matter (%)	Soil chemical analysis P	K	Ca	Mg
										(ppm)			
1979													
Ascension	Burnside	J. & R. Robert	Setre	Bragg	36	Yes	vfsl	5.6	1.54	236	164	3227	682
Assumption	Napoleonville	R. Landry	Setre	Lee 74	36	Yes	sicl	6.0	1.59	159	95	3131	651
Beauregard	Dry Creek	M. & D. Farmer	Rudy Patrick	Davis	30	No	c	5.8	4.14	58	302	4000+	1000+
Beauregard	Longville	S. Jacobson	Rudy Patrick	Ransom	32	No	vfsl	6.0	1.88	45	68	622	129
Caddo	Shreveport	K. Bell	Setre	Forrest	38	Yes	sicl	7.6	1.97	268	444	4000+	853
Calcasieu	Lake Charles	L. & D. Hoffpauir	Rudy Patrick	Terra Vig	30	Yes	sil	5.8	2.55	37	157	813	170
E. Feliciana	Clinton	J. Freeman	Nitragin Kalo	Bragg	14	Yes	sl	6.4	1.25	44	59	552	75
E. Feliciana	Clinton	L. Harvey	Triple Noctin	Forrest	32	No	sil	5.5	1.47	59	94	456	62
E. Feliciana	Clinton	S. Guttzeit	Nitragin	Forrest	7	Yes	sil	6.9	2.64	10	123	1183	322
Grant	Colfax	G. Randolph	Nitragin Kalo	Ransom	36	No	sil	6.5	0.39	160	86	682	186
Iberia	New Iberia	A. Guillotte	Triple Noctin	Forrest	36	No	sil	5.0	2.12	16	125	703	221
Iberville	Plaquemine	D. Purpera	Nitragin	Forrest	38	Yes	sil	6.9	2.84	277	140	2667	598
Lafayette	Youngsville	D. Viator	Nitragin	Forrest	35	Yes	sil	6.2	1.20	25	47	1152	146
Rapides 1	Cheneyville	W. Ballich	Rudy Patrick	Davis	40	No	c	6.0	2.31	110	257	3331	950
Rapides 2	Cheneyville	W. Bollich	Rudy Patrick	Terra Vig	40	No	c	6.4	2.40	116	387	4000+	1000+
Rapides 3	Cheneyville	W. Ballich	Rudy Patrick	Tracy	40	No	c	7.0	2.31	123	345	4000+	1000+
Rapides 5[1]	Cheneyville	W. Ballich	Rudy Patrick	Centennial	40	No	c	7.6	1.40	146	299	4000+	871
St. John Baptist	Edgard	S. Rodrique	Nitragin	Forrest	30	Yes	sicl	7.5	1.15	217	111	3791	671
St. John Baptist	Edgard	S. Rodrique	Nitragin	Forrest	30	Yes	sicl	7.6	1.30	204	53	1943	432
Tensas	St. Joseph	W. Butler	Setre	Davis	10	Yes	c	5.0	1.68	15	49	261	54
Vernon	Leesville	C. Boley	Rudy Patrick	Forrest	10	Yes	sl	6.7	0.58	29	30	350	32
W. Baton Rouge	Port Allen	C. & N. Arnold	Setre	SRF 450[2]	36	Yes	sil	6.5	0.96	172	83	2386	527
1980													
Acadia	Rayne	G. Zaunbrecher	Rudy Patrick Kalo	Ransom	32	No	sil	6.1	0.63	35	75	874	849
Ascension	Donaldsonville	J. & R. Robert	Triple Noctin	Bragg	36	No	c	6.4	2.02	23	54	1339	524
Bossier	Bossier City	J. Robinson	Rudy Patrick	Bossier	30	No	sil	6.1	0.63	257	467	4000+	1000+
Lafayette	Youngsville	D. Viator	Nitragin	Hood 75	35	No	sil	6.4	0.96	17	75	1012	59

(Continued)

Table 1. — (Continued)

Parish	Nearest tawn	Caaperating grawer	Inaculent brand	Seed variety	Raw spacing (inches)	New saybean land	Sail texture	pH	Organic matter (%)	Sail chemical analysis P	K	Ca	Mg
										-------	(ppm)	-------	
				1981									
Acadia	Dusan	G. Zaunbrecher (1)	Rudy Patrick	Ransam	32	Na	sicl	5.8	0.78	98	107	1587	440
Acadia	lata	W. Garber (1)	Nitragin	Davis	30	Na	sil	6.3	1.15	120	46	999	144
Acadia	lata	W. Garber (2)	Nitragin	Davis	30	Na	sil	6.4	1.15	199	248	821	88
Acadia	Rayne	G. Zaunbrecher (2)	Rudy Patrick	Centennial	32	Yes	c	6.1	1.28	29	92	1621	570
Lafayette	Yaungsville	D. Viatar	Nitragin	Farrest	35	Na	sil	5.2	1.28	241	397	4000+	818
Rapides	Cheneyville	W. Ballich	Nitragin	Tracy	30	Na	c	7.0	1.04	47	86	717	76
Rapides	Cheneyville	W. Bollich	Nitragin	Terra Vig 606	30	Na	c	6.7	0.96	141	473	4000+	1000+
Rapides	Cheneyville	W. Ballich	Nitragin	Terra Vig 708	30	Na	c	7.2	1.28	141	401	3997	1000+
Richland	New Light	T. Herringtan	Nitragin	DPL 506	38	Na	c	7.1	1.41	208	405	4000+	1000+
St. Landry	Melville	J. Artall	Rudy Patrick	Farrest	36	Yes	c	7.4	1.41	253	237	3792	763
St. Landry	Palmetta	G. Hubbard	Nitragin	Centennial	B.C.[3]	Na	c	6.8	1.91	151	408	4000+	790
St. Mary	Franklin	B. Allain	Nitragin	Bragg	34	Yes	c	6.6	1.91	69	169	3735	759
W. Batan Rauge	Part Allen	C. Wilkinson	Nitragin	Farrest	36	Na	c	6.3	0.78	256	281	2979	611
				1982									
Acadia	Rayne	G.& F. Zaunbrecher	Rudy Patrick	DPL 345	32	Na	sicl	5.8	2.40	38	128	2242	653
Rapides	Cheneyville	W. Ballich	Nitragin	Tracy	30	Na	c	—[4]	—	—	—	—	—
St. Landry	Melville	J. Artall	Nitragin	Farrest	36	Yes	sicl	7.3	1.74	181	232	3992	672

[1] Field number 4 was nat sample; however, yield data was gathered. It was nat new saybean land.

[2] SRF 450 is a Graup IV maturity graup variety and was used in attempt ta daublecrap saybeans and sugarcane.

[3] B.C. — Broadcast.

[4] Na sail sample taken in 1982.

Data in Table 2 summarize nodulation, i.e. nodule number and dry weight, and nitrogen (C_2H_2) fixing abilities of the plants, plus seed yield for the entire period. The first row (YES) of values for each location gives the average values found on the plants grown from inoculated seed, while the second row (NO) values are the data from plants grown from uninoculated seed. These data summarize the results gathered from 43 separate tests. In a few instances, one grower provided two or more different fields in a single year and several growers cooperated for 2 or more years, but no two tests were ever planted on the same field during the 4 years of the experiment. Occasionally something interfered with gathering either nodulation and nitrogen-fixing data, or yield data, but never were both parameters lost from any of the test locations.

No statistically significant differences in any of the six parameters were noted at 22 of the 43 fields during the 4 years of the test. These fields comprised 51 percent of the total population. Statistical differences, both increases and decreases, were therefore detected in at least one parameter during the growing season at 49 percent of the locations.

Summarizing the statistical data for nodulation (nodule number and nodule dry weight) indicated five statistical decreases in nodule number with no increases in 1979. One location had a significant increase in nodule weight, while two had significant decreases. In 1980, two significant increases occurred in nodule weight with one decrease in nodule number. Three statistically significant increases occurred in nodule number and in dry weight in 1981 while one significant decrease in each parameter also occurred. In 1982, there was one significant decrease in nodule number.

Nitrogen (C_2H_2) fixation parameters in 1979 indicated significantly higher values for C_2H_4 produced per nodule at two locations with one corresponding decrease. Five C_2H_4 values per plant and three per gram of nodule were lowered significantly by the inoculation treatments. In 1980, one value was significantly lower than the inoculated value. This was the value of C_2H_4 produced per nodule at the Acadia location. In 1981, results were split almost evenly with two significant increases and two decreases in C_2H_4 produced per plant and per gram of nodule, and two increases versus three decreases with respect to C_2H_4 produced per nodule. Significant decreases were noted at one location (St. Landry) for all three values in 1982.

Seed yields were analyzed to test for differences of inoculated versus uninoculated soybeans and to estimate the magnitude of seed yield differences. Separate analyses were also conducted on previously cropped soybean land and on new, first-year bean land. Results of these analyses indicated that inoculated test areas yielded significantly higher ($P < .05$) than uninoculated areas. The average yield difference was 1.9 bushels per acre. Confidence limits (95 percent) for the average yield increases were 0.3 to 3.4 bushels per acre.

Table 2. — Nodulation and nitrogen fixation parameters and seed yield of soybeans grown with and without seed inoculation, 1979-82

Parish/grower	Sampling date	Inoculation	Nodules No.	Nodules Dry wt. (mg)	μMC_2H_4 Produced per hour per: Plant	Nodule	g nodule	Seed yield (bu/a)
1979								
Ascension	8/5	Yes	27	225	2.22	0.0871	9.58	35.4
J. & R. Robert		No	43	211	2.14	0.5979	10.98	36.2
Assumption	7/31	Yes	169	638	1.86	0.0127	2.65	24.9
R. Londry		No	160	516	2.24	0.0104	4.08	22.9
Beauregard	8/21	Yes	27	190	0.13	0.0047*	2.19	34.9
M. & D. Farmer		No	26	167	0.06	0.0018	2.58	42.1*
Beauregard	8/21	Yes	32	124	1.19	0.0383	0.10	—
S. Jacobsan		No	48*	185*	1.97	0.0444	0.11	—
Caddo	8/29	Yes	26	96	4.49	0.2451	62.29	—
K. Bell		No	21	61	22.03	2.0874	56.51	—
Calcasieu[1]	8/21	Yes	—	—	—	—	—	32.2
L. & D. Hoffpauir		No	—	—	—	—	—	34.9
E. Feliciana	9/6	Yes	38	336	0.36	0.0061	3.76	—
J. Freemon		No	96*	242	1.60*	0.0167*	23.05	—
E. Feliciana	9/6	Yes	44	105	0.34	0.0429	6.76	42.9
L. Harvey		No	63	114	0.22	0.124	6.52	39.4
E. Feliciana	9/6	Yes	22	502*	0.83	0.0542	2.20	39.7
S. Guttzeit		No	27	251	2.50*	0.1002	16.28*	34.3
Grant	8/7	Yes	151	481	2.08	0.0143	4.60	44.7
G. Randolph		No	196	641	3.06	0.0165	4.89	43.1
Iberia	7/30	Yes	39	81	1.90	0.0539	24.15	32.2*
A. Guillote		No	32	58	1.19	0.0336	18.44	25.6
Iberville	8/6	Yes	33	153	7.79	0.2457	47.36	43.1*
D. Purpera		No	27	89	5.33	0.2754	60.74	32.8

(Continued)

Table 2. — (Continued)

Parish/grower	Sampling date	Inoculation	Nadules Na.	Nadules Dry wt. (mg)	μMC_2H_4 Produced per hour per: Plant	Nodule	g nodule	Seed yield (bu/a)
Lafoyette	8/27	Yes	74	475	8.28	0.1064*	16.70	—
D. Viator		No	115*	547	6.36	0.0567	11.21	—
Rapides 1	7/31	Yes	38	225	4.38	0.1176	17.68	46.2
W. Bollich		No	72	373*	8.65*	0.1372	24.32*	49.0
Rapides 2	7/31	Yes	30	158	6.76	0.2359	42.17	51.4
W. Bollich		Na	47*	220	11.95*	0.2589	55.81	50.4
Rapides 3	7/31	Yes	48	233	6.90	0.1545	31.79	—
W. Ballich		No	42	247	7.57	0.1836	30.55	—
Rapides 4[1]	—	Yes	—	—	—	—	—	37.1
W. Ballich		Na	—	—	—	—	—	37.7
Rapides 5[1]	—	Yes	—	—	—	—	—	48.9
W. Bollich		Na	—	—	—	—	—	47.6
St. Jahn Baptist	7/28	Yes	50	234	0.67	0.0148	2.85	—
S. Radrique		Na	89	179	1.74*	0.0235	9.56*	—
St. John Boptist	7/28	Yes	2	38	0.25	0.1008	3.37	—
S. Rodrique		No	2	49	0.36	0.2200	4.54	—
Tensos	8/23	Yes	34	105	1.12	0.0331	9.13	18.6
W. Butler		No	51	223	1.79	0.0298	6.23	16.2
Vernon[1]	—	Yes	—	—	—	—	—	23.8
C. Bailey		No	—	—	—	—	—	24.5
W. Batan Rouge	7/30	Yes	76	551	2.82	0.0263	3.76	26.7
C. & N. Arnold		Na	119	590	3.85	0.0429	5.41	29.8
1980								
Acadia	7/21	Yes	47	135	8.83	0.1635	49.35	—
G. Zaunbrecher		Na	52	124	11.20	0.1775	49.71	—
	8/5	Yes	39	192	11.41	0.0784	29.99	45.0
		No	40	184	9.10	0.1324*	28.19	44.8

(Continued)

Table 2. — (Continued)

Parish/grower	Sampling date	Inoculation	Nodules		μMC$_2$H$_4$ Produced per hour per:			Seed yield (bu/a)
			No.	Dry wt. (mg)	Plant	Nodule	g nodule	
Ascension	8/25	Yes	54	188	5.33	0.1123	40.11	—
J. & R. Robert		No	61	241	5.92	0.1103	46.60	—
Bassier	9/10	Yes	131	429	1.74	0.0099	2.93	42.3*
J. Robinson		No	105	394	2.04	0.0152	4.40	28.8
Lafayette	7/21	Yes	15	45	0.88	0.0584	19.25	—
D. Viatar		No	25	130*	0.27	0.0108	2.07	—
1981								
Acadia	7/22	Yes	40**	164*	2.70	0.0631	15.33	—
G. Zaunbrecher (1)		No	21	88	1.22	0.0605	13.17	—
	8/11	Yes	49	225	6.28	0.1297	27.92	31.6
		No	32	135	3.98	0.1417	30.18	27.5
Acadia	7/15	Yes	60	313	2.92	0.0746	15.52	—
W. Garber (1)		No	76	419	2.51	0.0360	6.38	—
	8/5	Yes	40	259	2.34	0.0501	7.42	38.7
		No	58	355	3.47	0.0593	9.32	35.4
Acadia	7/15	Yes	60	313	2.21	0.0370	6.98	—
W. Garber (2)		No	76	419	3.32	0.0455	7.51	—
	8/5	Yes	77	440	6.43	0.0728	11.51	42.4
		No	57	422	10.77	0.1734	22.81	41.8
Acadia	7/15	Yes	31	179	4.76	0.1593	27.15	—
G. Zaunbrecher (2)		No	43	160	4.85	0.1132	30.91	—
	8/5	Yes	48	304	4.09	0.0856	14.12	39.5
		No	54	264	5.09	0.0972	20.37	39.1
Lafayette	7/9	Yes	24	125	3.94	0.1685	33.23	—
D. Viatar		No	26	149	4.08	0.1793	29.02	—
	7/30	Yes	44	366	14.22	0.3483	39.46*	37.6
		No	63	376	11.35	0.2358	29.79	35.5

(Continued)

Table 2. — (Continued)

Parish/grower	Sampling date	Inoculation	Nodules		μMC$_2$H$_4$ Produced per hour per:			Seed yield (bu/a)
			No.	Dry wt. (mg)	Plant	Nodule	g nodule	
Rapides W. Bollich (1)	7/23	Yes	27	200	1.97	0.0897	12.90	—
		No	24	195	1.80	0.0837	12.43	—
	8/17	Yes	29	218	1.00	0.0385	4.53	44.2
		No	38	278	1.31	0.3770	4.91	42.2
Rapides W. Bollich (2)	7/23	Yes	23	150	0.54	0.0232	4.40	—
		No	23	137	1.18	0.1050	17.01	—
	8/17	Yes	17	120	0.12	0.0077	1.12	36.3
		No	16	121	0.49**	0.0276**	4.55	33.3
Rapides W. Bollich (3)	8/17	Yes	20	106	1.97	0.0763	15.40	—
		No	24	91	1.86	0.0694	16.49	—
	8/29	Yes	28	90	0.90	0.0346	11.41	31.7
		No	78**	198**	7.67**	0.1051**	38.41**	32.1
Richland T. Herrington	7/13	Yes	69	275	6.25	0.0964	23.62	—
		No	82	291	6.06	0.0738	21.70	—
	8/3	Yes	92	367	1.99	0.0231*	7.22	25.1
		No	81	246	0.88	0.0100	3.35	25.8
St. Landry J. Artall	7/10	Yes	24	181	11.49*	0.6566	69.13	—
		No	17	104	5.35	0.3014	44.95	—
	7/31	Yes	69	232	3.64	0.0883	19.33	50.1*
		No	69	212	3.88	0.1396	24.48	41.4
St. Landry G. Hubbard	7/31	Yes	6	25	0.56	0.0621	12.73	—
		No	4	17	0.20	0.0192	3.52	—
	8/17	Yes	4	28	0.42	0.1310	10.20	—
		No	2	20	0.56	0.1884	15.68	—
St. Mary B. Alloin	7/13	Yes	39	364	12.44**	0.3184**	33.27**	—
		No	35	222	2.56	0.0903	12.37	—
	8/3	Yes	56**	455**	8.97	0.1684	20.03	58.8*
		No	31	298	6.24	0.1955	22.64	52.8

(Continued)

Table 2. — (Continued)

Parish/grower	Sampling date	Inoculation	Nodules		μMC$_2$H$_4$ Produced per hour per:			Seed yield (bu/a)
			No.	Dry wt. (mg)	Plant	Nodule	g nodule	
W. Baton Rouge	7/8	Yes	46	146	6.10	0.1242	41.47	—
C. Wilkerson		No	34	114	4.16	0.1233	35.02	—
1982								
Acadia	7/21	Yes	102	292	2.16	0.0240	7.74	—
G. & F. Zaunbrecher		No	80	316	2.38	0.0297	8.06	—
	8/10	Yes	87	259	5.28	0.0604	20.03	45.9
		No	87	294	6.55	0.0787	22.66	47.8
Rapides	9/5	Yes	34	194	2.35	0.0687	12.32	—
W. Bollich		No	40	228	3.38	0.0871	14.71	—
St. Landry	7/21	Yes	60	321	1.63	0.0261	5.33	—
J. Artall		No	66	329	4.44	0.0725*	12.91**	—
	8/11	Yes	72	300	1.56	0.0270	6.58	52.8
		No	124**	361	2.16	0.0194	5.98	51.6

[1] It was not possible to acquire this data at this location.

*Significantly higher at .05 level of probability.

**Significantly higher at .01 level of probability.

The average seed yield increase from the use of inoculum on new soybean land was 2.4 bushels per acre with 95 percent confidence limits of −0.1 to 4.9 bushels per acre. The average seed yield increase on land previously cropped to soybeans was 1.5 bushels per acre with 95 percent confidence limits of −0.4 to 3.5 bushels per acre. Neither of the latter two were significant because of the lower number of observations per mean when the entire test (inoculum versus no inoculum) was split into inoculum versus no inoculum for the 12 new land sites or the 19 old bean field sites.

Discussion

Nodulation and nitrogen (C_2H_2) fixation parameters did not support the need for soybean seed inoculation at planting. Values in 1979, 1980, and 1982 were predominantly against the practice of inoculation while 1981 values were slightly in favor of seed inoculation. Nodulation and nitrogen fixation values are evaluated during a 1-hour period chosen arbitrarily at flowering and pod-fill and may not totally represent what happens during an entire growing season.

Seed yield values presented a different picture with respect to the need for seed inoculation. No reason can be given for the significant decrease in yield at the Beauregard location in 1979. Occasionally a strain of *Rhizobium japonicum* can cause temporary adverse effects in soybean plants but these influences are usually overcome within a period of several days and are never reflected at harvest time. The statistically significant increases in seed yield over all locations does, however, present a good argument to advocate preplant inoculation of soybean seed on both ‘‘old’’ and ‘‘new’’ soybean land.

The seed yield increase at the Iberia locations in 1979 could possibly have been a molybdenum and/or fungicide response. The inoculant used at that site contained both molybdenum and fungicide mixed with the nodulating bacteria. Since the soil had a very acid pH value of 5.0, a molybdenum response may have been measured. There was no apparent fungal damage in the uninoculated plots, which would rule out any fungicide effect. The pH values were considered quite acidic for soybean growth and the plants could have been in need of additional molybdenum for maximum plant growth and yield.

The remaining three seed yield increases all occurred on new, first-year bean land. Although statistical analyses did not demonstrate significance with respect to yield increases from inoculation on new land in general, this data would present a strong argument for the use of inoculum when one is growing beans on land with no previous history of soybean growth.

Conclusions

Nodulation and nitrogen (C_2H_2) fixation test parameters did not present much evidence to support the need for soybean seed inoculation at planting. However, seed yield values did indicate some statistically significant responses. Of the 43 test areas, yield data were gathered at 31. Five statistically significant increases in seed yield were found. This comprised 16 percent of the test locations. One significant decrease (3 percent) in seed yield also occurred. Of the five significant increases in seed yield, one could possibly have been a molybdenum response by the plants that were grown in a soil that was considered quite acidic for soybean growth. Although it is certainly a desirable management practice to provide small amounts of molybdenum to the plants under these acidic conditions, molybdenum in direct combination with live rhizobia in an inoculum is not a good way to provide it. There is good evidence (Burton and Curley, 1966; Hiltbold et al., 1980; Skipper et al., 1980) that inoculants which contain molybdenum and/or fungicide (such as Triple Noctin did in 1979) probably did not contain many live rhizobia due to the lethal effects of the molybdenum and fungicide. These combination products are now usually sold in separate containers to be mixed just prior to inoculating and sowing the seed. Each grower should determine his own economics if he is faced with a need for rhizobial seed inoculant and molybdenum and/or fungicide. There are ways to accomplish this that are compatible with the rhizobia.

The other four significant yield increases in these tests were attributed to inoculation of seed with the inoculant-rhizobia. That was still a 13 percent overall response to inoculation. In all instances, the inexpensive peat-base inoculants were used.

These results indicated that a soybean grower could easily decide not to inoculate his seed and stand a good chance of suffering no ill effects with respect to final seed yield. In no instance did any grower ever suffer a crop failure due to lack of inoculation. However, the cost of seed inoculation with the inexpensive but adequate peat-base materials is very low. Although peat-base products vary in cost from location to location, it is still possible to inoculate at a cost of less than $1.00 per acre. The cost in time is only a few minutes at planting. Planter box inoculation, although not the best way to inoculate, requires no additional equipment with the exception of a stick to stir the seed and inoculum together. No additional field transportation or planting costs are involved. The cost of the inoculum, compared with the cost of soybean seed, fertilizer, herbicides, fungicides, nematocides, adjuvants, fuel, etc., is negligible. Statistical analyses of data from all locations did indicate that a soybean grower could expect a significant increase of about 1.9 bushels per acre from inoculation. This would more than pay for the peat-base inoculum.

In fact, even after subtracting 0.2 bushels per acre as the cost for inoculum, we can say with 95 percent confidence that the expected yield profit from inoculation in Louisiana would be about 0.1 to 3.2 bushels per acre.

Soybean seed inoculation with a reputable inoculant seems like an inexpensive form of insurance for the Louisiana soybean grower regardless of whether he is planting on land that will be put into soybeans for the first time or on "old" soybean land.

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Effects of STORAGE METHOD on LOSSES and QUALITY CHANGES in ROUND BALES of RYEGRASS and ALFALFA HAY

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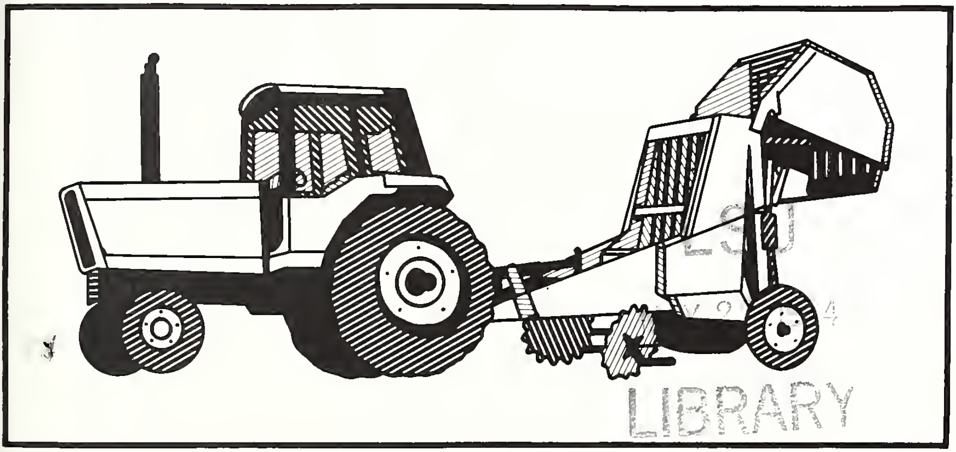

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Effects of Storage Method on Losses and Quality Changes in Round Bales of Ryegrass and Alfalfa Hay

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According to a recent (1980) USDA report, hay ranked third nationally in dollar value of estimated total agricultural production as follows: corn—$14.9 billion, soybeans—$12.2 billion, and hay—$6.6 billion. The value of hay is often overlooked because most hay is used on farms where it is produced. In 1980, approximately 355,000 acres of hay was harvested in Louisiana.

Every year livestock producers in Louisiana and the humid south need stored feeds during periods when low temperature and/or limited soil moisture restrict plant growth for grazing. Hay, a major stored feed, is an expensive and labor demanding enterprise. Recently, producers have, for the most part, reduced labor requirements by baling hay in large packages rather than conventional square bales. Research has shown that hay stored outside in large bales may undergo substantial physical changes and quality deterioration. Method of storage has been identified as the most important factor affecting these changes. The problem can be most critical in Louisiana because hay quality is often reduced by high humidity and frequent rains prior to baling. To maintain quality, harvested forage should be cured without rainfall and baled at a maximum of 15 percent moisture. Otherwise, hay losses from molding and rotting are intensified in bales stored on the ground, a common practice with large round bales, compared with hay stored in a barn.

Large round hay bales, generally stored outside until fed to cattle, are subjected to weather-induced spoilage. Crop species of hay and size, shape, and density of bales affect storage losses.

This study was conducted to evaluate the effects of six storage methods on quantitative and qualitative changes in ryegrass and alfalfa hays stored as large round bales. Included among qualitative parameters was available protein, that useable by ruminant animals, as affected by heat generated within the bale core during storage.

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Review of Literature

Several studies have been conducted to evaluate storage changes in large round bales of hay. Rider and McMurphy (*9*)[3] reported that round bales of alfalfa, bermudagrass, and forage sorghum should be stored on a well-drained site near the feeding area to minimize quantitative losses due to hay rotting when in contact with the ground. Some of the losses result from hay falling off the bales when moved, with distance of the move being a factor of consideration. Similar losses were found with ryegrass stored on the ground by Louisiana workers (*11*).

Compositional changes and hay losses in large bales stored outside were evaluated by Lectenberg et al. (*5*). Deterioration around the top and sides and at the bottom of bales, where hay was in contact with moist soil, reduced dry weight of alfalfa bales 10 percent and changed hay composition. Nutritive value of hay, measured by *in vitro* digestible dry matter (IVDDM), disappearance decreased, but crude protein percentage increased. Storing bales on crushed rock to prevent soil contact reduced dry matter losses 57 percent compared with hay stored on the ground. Total elimination of weathering losses occurred when hay bales were stored without weathering.

The need for protecting large round bales of alfalfa hay from weathering was demonstrated by Bledsoe et al. (*2*) and Verma (*14*). Hay in bales protected from weather were higher in quality than that left unprotected. Moisture penetrated large round bales of alfalfa 2 to 4 inches in depth when stored outside, and surface hay was 5.5 percent lower in protein and 16 percent less digestible than interior hay of the bale (*14*). Bledsoe et al. (*2*) further showed that hay baled with an initial moisture above 30 percent resulted in poorer quality after storage than that baled below 30 percent.

Storage losses of alfalfa, bermudagrass, and sorghum-sundangrass in large round bales were determined by Rider et al. (*8*). Inside storage or protection by black polyethylene circumferential wrapping of bales minimized both dry matter and digestible dry matter losses for all hays. Circumferential wrapping most effectively maintained total physical mass of bales. Bermudagrass bales, as a result of forming an excellent thatch on the outer surface, were most resistant to weathering of all forages investigated. Shrinkage was reported to be about 15 percent on the average for an 8-month outside storage period of large round alfalfa bales (*13*). A positive relationship was found between bale volume and its overall measurement.

Hay storage studies (*6*) conducted at Auburn University resulted in the following recommendations: 1—if barn space is available, hay should be stored inside, 2—when storing outside, the storage site should be well drained and located as close to the hay field and feeding area as possible,

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[3] Italic numbers in parentheses refer to Literature Cited, page 19.

3—if available, store bales on old tires, timber, or other material that will reduce moisture around bottom of bales, and 4—do not store bales under trees.

Procedure

This study was conducted at the Southeast Research Station, Franklinton. Gulf ryegrass and Apollo alfalfa were test crops in 1980, and Gulf ryegrass alone was used in 1981. In 1980, ryegrass was field cured to approximately 20 percent moisture content and alfalfa to approximately 10 percent; in 1981 ryegrass was field cured to approximately 12 percent moisture. The bales were formed by a chain-driven, round-bale machine and stored as follows: (1) on 8-inch gravel bed, (2) directly on the ground, (3) on elevated wooden racks with plastic covering the hay, (4) on elevated wooden racks with hay uncovered, (5) on automobile tires, and (6) inside a barn. The wooden racks consisted of four treated posts driven into the ground in an 18-inch by 36-inch rectangle, with 1-inch by 6-inch treated boards 18 inches long nailed to two posts on each side to form a support for the bales 16 inches above the ground. In 1981 the wooden racks were modified as shown in Figure 1.

Alfalfa bales were placed on one of the following three treatment systems for storage: (1) elevated wooden racks with hay uncovered; (2) elevated wooden racks with plastic covering the hay; and (3) inside a barn.

Ryegrass was cut May 5, 1980, baled May 10, and four bales of each of the six storage treatments were placed in an experimental storage area May 12.

Four alfalfa bales per storage mode were placed in storage June 5, 1980, after forage cut June 2 was baled June 4. Before storing, all bales were weighed and measured and forage samples obtained with a power-driven core sampler (*4*).

Two of the four ryegrass bales from each mode of storage were processed in December 1980 to determine handling, storage, and animal refusal losses; the remaining two bales of each treatment were left in storage through the 1980-81 summer-winter season before obtaining hay loss data.

Alfalfa bales were kept in storage from June 5, 1980 to May 12, 1981, at which time they and the remaining two bales per storage mode of ryegrass were sampled, weighed, and measured to terminate the first year of the study.

All ryegrass and alfalfa bales were core-sampled for laboratory analyses initially and at 30-day intervals during the remainder of the storage period. Quality measurements of ryegrass hay were made from chemical analyses, *in vitro* digestible dry matter (IVDDM), and *in vivo* digestible dry matter (DDM) determinations. Quality measurements of alfalfa were based on chemical analyses and IVDDM.

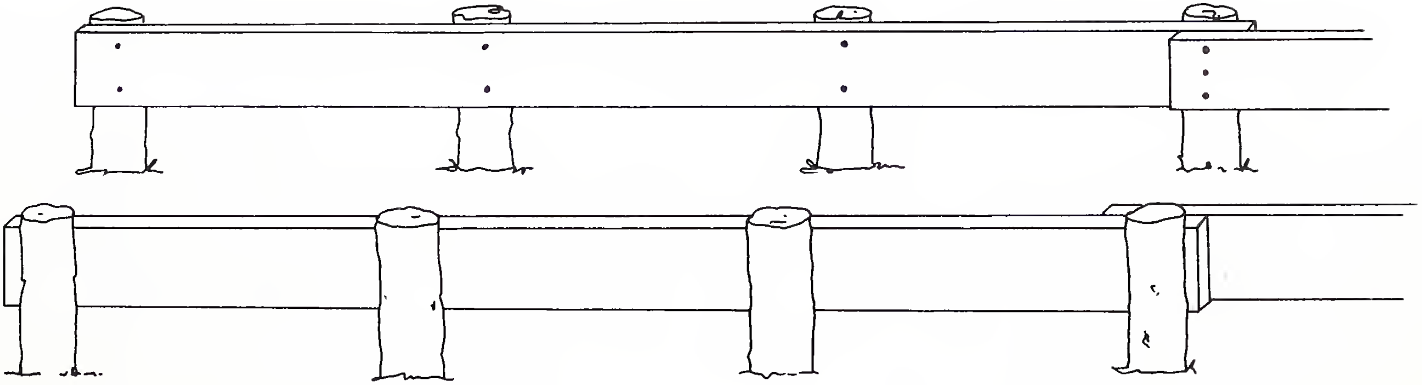

Figure 1. Schematic and specifications of a round hay-bale storage rack, as modified in width, and used during 1981.
Treated post: 3' long, 1½' in ground.
Siderails: 1'' x 6'' treated lumber.
Post spacing: 7' lengthwise, allowing boards to overlap 6'', and 24'' in width.
The posts were driven into the ground for stability.
Nail: 16-penny common.

Rainfall accumulation of 20 inches was recorded in 1980 during the 7-month storage period, after which the first determination of quantitative losses was made. During the last 5 months, December 1980 through April 1981, of the 12-month total storage of the 1980-harvested hays, 23.3 inches of rain fell. Total rainfall for the 12-month period, May 1980 through April 1981, was approximately 25 percent less than that of the same period during 1979-80. Storage losses probably vary among storage periods, depending on rainfall level.

In the second year of the study, ryegrass forage was cut April 23, 1981 and baled and stored April 30. Four storage methods were employed: on the ground, uncovered hay on elevated racks, covered hay on elevated racks, and in the barn. Four ryegrass bales were included in each storage mode. All bales were weighed, measured, and core-sampled April 30, May 12, June 11, August 7, and October 13. Rainfall of 20.02 inches was recorded during the 6-month storage period, averaging 3 to 5 inches per month, except for October when only 1.05 inches fell.

Following 7-month and 12-month storage periods in 1980 and the 6-month storage in 1981, one bale from each storage mode was sliced (*12*), to assess interior damage, chopped in a hammer mill, and fed to sheep in a digestion trial. Another bale from each of the storage systems was fed to adult Holstein cows *ad libitum* to measure animal refusal after 7-month storage in 1980 and after 6-month storage in 1981.

Core samples of all stored hays, collected at various intervals, were analyzed in the laboratory to determine dry matter, structural carbohydrates [neutral-detergent fiber (NDF), acid-detergent fiber (ADF), cellulose, and acid-insoluble lignin (AIL)] as outlined by Goering and Van Soest (*3*). *In vitro* digestible dry matter (IVDDM) was determined by the modified Van Soest procedure (*7*). Hemicellulose was calculated as the difference between NDF and ADF. Crude protein (CP) was determined as outlined by AOAC (*1*), and available protein (AP) was calculated by subtracting the fiber-bound protein from total crude protein. Fiber-bound, or ADF protein, was determined by extracting ADF from forage and determining Kjeldahl nitrogen of the ADF fraction. Duncan's New Multiple-Range Test, as described by Steel and Torrie (*10*), was used to determine differences in treatment means.

Results and Discussion

1980 Harvest of Ryegrass

The decrease in volume of each large round bale is defined as shrinkage. Bales of both ryegrass and alfalfa stored in the barn had minimum shrinkage, as well as shape deformation, when compared to bales in outside storage (Table 1). Ryegrass bales stored on the ground exhibited maximum

Table 1.—Initial bale weight, density, and shrinkage of large round bales after 7 and 12 months in six storage systems, 1980-81

Storage system	Initial[1] wt, lbs	Initial[1,3] density	Shrinkage[2], 7 mo, %	Shrinkage[2], 12 mo, %
		Ryegrass		
Gravel	879	6.85	30.3	36.9
Ground	927	6.84	37.7	51.0
Rack	824	5.74	26.7	29.8
Rack w/cover	950	6.25	17.4	18.3
Tires	856	6.09	29.5	32.1
Barn	892	7.02	5.7	14.2
		Alfalfa		
Rack	1095	7.96	6.69	7.89
Rack w/covers	1125	7.95	5.92	6.22
Barn	1075	10.21	6.16	6.16

[1] Each value is a mean of four bales.

[2] Each value is a mean of two bales.

[3] Pounds per cubic foot.

shrinkage, over 50 percent after 12 months of storage. Alfalfa bales, being more densely packed, showed much less shrinkage than ryegrass bales at comparable periods and methods of storage. Alfalfa bales were heavier and drier initially than the ryegrass bales.

Handling loss is defined as hay left at the storage site following bale removal. Losses for ryegrass bales stored in the barn and on racks with cover after 7 months were not measurable (Table 2). Even after 12 months in storage, ryegrass bales in the barn showed no handling loss. Ryegrass bales stored on tires and on the ground showed highest handling losses of all systems. Those bales were wet at the bottom and the rotted portion of hay was left at the storage site when the bales were removed. Rainwater was trapped in tires of that storage mode and proved to be detrimental to hay preservation. The condition was observed when bales were sectioned.

Dry matter loss was high for all ryegrass bales, except those stored in the barn and on racks with cover (Table 2). Losses in dry matter approached 40 percent for ryegrass hay stored for 12 months on the ground. Storage on tires, on gravel, and on racks without cover resulted in dry matter loss of 30 percent or more.

Animal refusal losses during feeding of large round bales were determined only for ryegrass hay after seven months of storage. Bales stored on the ground were highest in refusal (Table 2). Animal refusal also was high for hay stored on gravel, while bales protected from weather showed the least animal refusal.

Total hay loss, a combination of handling, dry matter, and animal refusal, was 65 percent for ryegrass bales following 7 months of storage outside on the ground (Table 2). Bale storage on gravel and on tires resulted

Table 2.—Percentage losses after 7 and 12 months, from handling, storage, and animal refusal in feeding large round bales of ryegrass hay in six systems, 1980-81

	Losses[1]						
Storage system	Handling		Dry Matter		Animal refusal[2]		Total[2]
	7 mo	12 mo	7 mo	12 mo	7 mo	12 mo	7 mo
	%						
Gravel	1.2	4.0	31.2	31.9	16.8	—	49.2
Ground	15.0	12.4	27.6	39.8	22.0	—	65.2
Rack	5.2	5.0	26.0	31.8	6.3	—	37.5
Rack w/cover	0.0	1.7	12.3	11.1	1.5	—	13.8
Tires	2.0	17.8	35.4	33.0	6.3	—	43.7
Barn	0.0	0.0	2.3	8.8	1.2	—	3.5

[1] Each value is a mean of two bales.

[2] Animal refusal values were not obtained for hay stored 12 months.

in losses exceeding 40 percent, and that hay stored on exposed racks approached 40 percent in total loss. Covered hay bales stored on racks had a total loss of 14 percent. In comparison, bales stored in the barn showed only 4 percent total loss.

1980 Quality Parameters in Ryegrass Hay

The effects of storage conditions on quality parameters of ryegrass hays after 7 and 12 months are shown in Tables 3 and 4. To relate changes in quality parameters during storage, values of each were expressed as a percentage of initial.

The initial dry matter (DM) content of ryegrass hay across all storage systems was 81.7 percent, with values ranging from 79.3 percent for bales stored on racks with cover to 85.4 percent for those stored on tires. Moisture content increased in all bales not protected from rain, with the greatest increase ($P<.05$) being exhibited by that stored on tires (Table 3). Bales stored on covered racks and in the barn decreased ($P<.05$) in moisture content.

Structural carbohydrates content (NDF, hemicellulose, ADF, and cellulose) of ryegrass hay was not affected after 7 months by storage method when expressed as a percentage of initial value. Only hemicellulose and AIL, of the structural carbohydrates, were affected ($P<.05$) by storage system after 12 months.

Initial crude protein (CP) content of ryegrass hay across all storage systems was 9.7 percent. After 7 months of storage, CP content tended to increase in all storage systems, but the increases were not significant. The additional 5 months of storage did not affect CP content of the hay.

Not all of the CP content of forages is available for animal utilization. Some of it is incorporated into the fiber tissue during growth of the plant. In addition, heat generated inside the haybale during storage causes a portion of the CP fraction to be bound to the fiber fraction, making the bound CP unavailable for animal utilization (*3*). The difference between CP and fiber-bound protein is called available protein (AP).

Initial AP content of ryegrass hay averaged 7.7 percent (Table 3). The AP content of ryegrass among storage modes changed considerably ($P<.05$) during storage, ranging from 93.7 percent of initial in hay stored on uncovered racks to 119.5 percent in hay covered on racks. Following 12 months of storage AP values ranged from 88.0 percent of initial for

Table 3.—Effects of storage conditions over time on chemical composition of ryegrass hay in large round bales, 1980-81

Storage system	Storage period			Relation to initial	
	Initial[1] 5-12-80	7 mo[2]	12 mo[3]	7 mo[2]	12 mo[3]
			Dry Matter, %		
Gravel	80.2	76.5b	74.8bc	94.7b	88.7cd
Ground	84.7	78.7bc	77.5a-c	91.9b	92.3c
Rack	79.6	72.0	71.4c	89.3b	95.1bc
Rack w/cover	79.3	87.5a	86.0a	112.1a	107.4ab
Tires	85.4	71.7c	67.4c	81.2b	76.8d
Barn	80.7	89.6a	88.8a	112.9a	114.8a
			Neutral-detergent fiber, %		
Gravel	66.6	69.9b	69.4c	105.9^{ns}	103.5^{ns}
Ground	68.6	70.9ab	71.6ab	103.9	105.2
Rack	67.9	70.3b	70.6bc	104.1	104.7
Rack w/cover	68.4	71.5ab	70.7bc	105.4	102.6
Tires	68.4	71.0ab	70.5bc	104.4	104.8
Barn	68.5	72.0a	73.0a	106.1	109.2
			Hemicellulose, %		
Gravel	25.7	25.1bc	24.1b	97.4^{ns}	90.6b
Ground	26.0	25.0c	25.2b	95.3	95.1b
Rack	26.8	26.3b	26.2b	97.7	97.2b
Rack w/cover	25.8	26.7a	25.9b	104.6	101.3ab
Tires	25.4	25.8bc	25.4b	101.9	100.1b
Barn	26.5	27.7a	29.0a	106.3	119.4a
			Acid-detergent fiber, %		
Gravel	40.9	44.8bc	45.2^{ns}	111.2^{ns}	111.7^{ns}
Ground	42.6	45.9a	46.4	109.3	111.6
Rack	41.1	44.0c	44.4	108.3	109.8
Rack w/cover	42.6	44.8bc	44.8	105.9	103.4
Tires	43.1	45.2ab	45.1	105.9	107.7
Barn	42.0	44.3bc	44.0	106.8	103.4
			Cellulose, %		
Gravel	35.0	35.2ab	34.1c	100.6^{ns}	97.6^{ns}
Ground	34.8	35.7a	36.4a	103.8	107.5
Rack	34.5	34.2b	34.4bc	99.1	99.9
Rack w/cover	35.9	36.0a	35.8ab	100.6	97.2
Tires	36.7	35.2ab	33.6c	95.3	93.8
Barn	35.0	36.0a	35.9a	103.7	100.0

Continued

Table 3.—Effects of storage conditions over time on chemical composition of ryegrass hay in large round bales, 1980-81 (cont'd)

Storage system	Storage period			Relation to initial	
	Initial[1] 5-12-80	7 mo[2]	12 mo[3]	7 mo[2]	12 mo[3]
	Acid-insoluble lignin, %				
Gravel	5.32	8.20a	8.30ab	163.1a	166.5a
Ground	5.37	8.27a	8.60a	163.7a	172.6a
Rack	5.65	7.73ab	8.22ab	142.9ab	148.8b
Rack w/cover	5.87	7.14b	7.37bc	125.0b	126.0c
Tires	5.04	7.74ab	8.64a	163.0a	180.5a
Barn	5.20	6.53c	6.54c	130.8b	116.6c
	Crude protein, %				
Gravel	9.2	11.6[ns]	12.3[ns]	132.7[ns]	128.8[ns]
Ground	8.9	11.4	11.5	133.7	139.4
Rack	10.9	13.2	13.6	124.7	125.7
Rack w/cover	9.0	11.4	11.2	131.7	130.7
Tires	9.9	12.4	12.8	129.6	124.2
Barn	10.1	11.5	11.8	117.9	109.4
	Available protein, %				
Gravel	6.9	7.4cd	7.5ab	110.2a	99.5c
Ground	6.7	6.5d	6.2b	97.5b	99.8c
Rack	8.5	8.0bc	7.4ab	93.7b	88.0c
Rack w/cover	7.5	8.6ab	8.1ab	119.5a	118.2a
Tires	8.1	7.9bc	8.1ab	97.8b	95.1c
Barn	8.4	9.1a	9.1a	111.6a	104.3b
	In vitro digestible dry matter, %				
Gravel	55.2	53.0b	52.3a	95.3b	92.6b
Ground	55.1	52.3b	52.4b	94.1b	94.7b
Rack	55.0	52.9b	52.5b	95.5b	95.6b
Rack w/cover	54.5	55.6a	56.0a	102.3a	103.7a
Tires	56.4	53.5b	52.9a	93.8b	92.3b
Barn	55.4	55.4a	56.5b	100.1a	102.5a

[1] Mean value of four bales when put in storage.

[2] Mean value of four bales and six sampling dates.

[3] Mean value of two bales and three sampling dates.

[a] Values within component columns with different letters differ significantly ($P < .05$).

[ns] Denotes non-significance at ($P < .05$).

ryegrass hay stored uncovered on racks to 118.2 percent for that covered on racks.

Storage of ryegrass hay in a barn and covered on racks had no effect on IVDDM after 7 and 12 months compared to initial values. All other storage systems decreased in IVDDM, but these decreases were very slight after 7 months. The decreases ranged from 7.7 percent for ryegrass hay stored on tires to 4.4 percent for hay stored on uncovered racks after 12 months of storage. *In vivo* digestibility of the quality parameters (NDF, HC, ADF, cellulose, CP, and DDM) of ryegrass hay stored on gravel, on the ground,

Table 4.—Effects of storage conditions over time on *in vivo* digestibility coefficients of nutrients and dry matter of ryegrass hay in large round bales, 1980-81

Storage period	NDF[1]	HC[2]	ADF[3]	Cell[4]	CP[5]	DDM[6]
Bales stored on gravel						
7 months	54.3[ns]	62.9[ns]	48.8[ns]	62.3[ns]	32.5[ns]	44.2[ns]
12 months	54.1	62.8	49.9	54.6	30.5	47.4
Bales stored on ground						
7 months	54.7[ns]	60.5[ns]	51.5[ns]	62.0[ns]	35.0[ns]	47.3[ns]
12 months	53.8	64.3	48.2	62.7	34.2	44.8
Bales stored on racks without cover						
7 months	56.2[ns]	65.6[ns]	49.9[ns]	67.3[ns]	41.2[ns]	46.3[ns]
12 months	56.0	59.5	50.3	62.7	40.2	48.9
Bales stored on racks with cover						
7 months	61.1a	71.3a	56.1[ns]	75.5a	49.6[ns]	51.4[ns]
12 months	57.3b	64.9b	53.3	62.8b	47.2	51.9
Bales stored on tires						
7 months	57.0[ns]	66.8a	51.0[ns]	70.6a	40.5[ns]	46.6[ns]
12 months	55.4	60.5b	52.4	63.1b	40.8	48.7
Bales stored in barn						
7 months	56.4b	62.1b	52.3[ns]	65.4[ns]	48.2[ns]	51.4[ns]
12 months	60.2a	68.1a	52.7	65.4	48.4	53.9

[1] Neutral-detergent fiber.
[2] Hemicellulose.
[3] Acid-detergent fiber.
[4] Cellulose.
[5] Crude protein.
[6] *In vivo* digestible dry matter.
[ns] Denotes non-significance at ($P<.05$).
[a] Values within columns and storage periods across systems with different letters differed significantly ($P<.05$).

and on racks without cover changed ($P<.05$) between 5 and 12 months of storage. The same was true for ADF, CP, and DDM in ryegrass hay stored covered on racks, on tires, and in the barn. *In vivo* digestibility decreased over time for HC and cellulose in ryegrass hay stored covered on racks and on tires. NDF and HC *in vivo* digestibility increased over time in ryegrass hay stored in the barn. After 12 months of storage overall DDM was highest in ryegrass hay stored in the barn, followed by that stored covered on racks, 53.9 percent and 51.9 percent, respectively.

1980 Quality Parameters in Alfalfa Hay

Initial DM content of alfalfa hay was 90.4 percent across all storage systems (Table 5). Hay stored on uncovered racks significantly increased in moisture during storage. Moisture content tended to decline during storage in alfalfa hay bales protected from the rain.

Content of structural carbohydrates (NDF, hemicellulose, ADF, and AIL) in alfalfa hay changed in storage, but the effects of storage methods were insignificant ($P<.05$), when measured as a percentage of initial values. Cellulose content was not affected by either storage method or time.

Initial average CP content of alfalfa hay was 16 percent, which tended to increase during storage. The increase was greater in hay uncovered on racks than in that covered on racks. Available protein in alfalfa hay did not differ significantly among systems after 12 months storage.

Percentage changes in IVDDM of alfalfa hay among the storage methods at 7 and 12 months were significant. Alfalfa hay stored in a barn was 5

Table 5.—Effects of storage conditions over time on chemical composition of alfalfa hay in large round bales, 1980-81

	Storage period			Relation to initial	
Storage system	Initial[1] 6-5-80	6 mo[2]	12 mo[3]	6 mo[2]	12 mo[3]
			Dry matter, %		
Rack	90.3	88.7b	85.9b	97.9b	94.8b
Rack w/cover	90.1	92.6a	91.6a	103.3a	102.0a
Barn	90.8	92.0a	91.2a	101.5a	100.7a
			Neutral-detergent fiber, %		
Rack	48.7	51.7a	53.4a	107.3^{ns}	109.0^{ns}
Rack w/cover	47.7	48.8b	49.9b	102.7	104.3
Barn	48.6	50.2ab	50.5b	104.2	104.2
			Hemicellulose, %		
Rack	9.2	11.9a	12.7a	133.6^{ns}	139.0^{ns}
Rack w/cover	9.4	10.7b	11.5b	126.8	128.7
Barn	9.2	11.3ab	11.5b	127.5	123.8
			Acid-detergent fiber, %		
Rack	39.6	39.9^{ns}	40.7a	100.9	101.7^{ns}
Rack w/cover	38.3	38.0	38.3b	99.3	99.6
Barn	39.4	39.0	39.0b	98.9	98.7
			Cellulose, %		
Rack	30.1	30.6^{ns}	31.0^{ns}	102.3^{ns}	102.7^{ns}
Rack w/cover	29.4	29.9	30.0	102.2	102.1
Barn	29.8	30.3	30.8	102.0	102.3
			Acid-insoluble lignin, %		
Rack	8.35	8.42a	8.75a	101.1^{ns}	104.2^{ns}
Rack w/cover	7.84	7.62b	7.87b	97.1	99.9
Barn	8.35	7.97b	7.89b	96.0	94.7
			Crude protein, %		
Rack	16.3	17.5a	17.6a	108.3^{ns}	109.0a
Rack w/cover	16.6	16.9b	16.7b	102.2	101.4b
Barn	15.2	15.9c	16.1c	105.6	106.5ab

Continued

Table 5.—Effects of storage conditions over time on chemical composition of alfalfa hay in large round bales, 1980-81 (cont'd)

Storage system	Storage period			Relation to initial	
	Initial[1] 6-5-80	6 mo[2]	12 mo[3]	6 mo[2]	12 mo[3]
	Available protein, %				
Rack	12.6	12.7ab	12.4ns	101.6ns	100.5ns
Rack w/cover	13.0	13.3a	12.9	102.6	100.2
Barn	11.6	12.1	12.3	106.1	106.9
	In vitro digestible dry matter, %				
Rack	58.5	59.1ns	58.5ns	101.3b	100.9b
Rack w/cover	58.4	59.5	59.6	102.3ab	102.5ab
Barn	57.1	59.5	59.7	105.0a	104.9a

[1] Mean value of four bales when put in storage.

[2] Mean value of four bales and six sampling dates.

[3] Mean value of four bales and three sampling dates.

[a] Values within component columns with different letters differ significantly ($P<.05$).

[ns] Denotes non-significance at ($P<,05$).

percent higher in IVDDM ($P<.05$) than that stored uncovered on racks. Irrespective of storage method, all alfalfa hays were as high or higher in IVDDM than initially.

1981 Harvests of Ryegrass

Losses in ryegrass hay stored during the 1981 season are reported in Table 6. Shrinkage was higher in bales stored on the ground (30.8 percent) and on racks without cover (27 percent) than for other storage systems. Shrinkage results were comparable to those obtained in the 1980 study. Shrinkage of bales stored in the barn, however, was greater than in the previous year. Excessive condensate (water) accumulation on the floor increased dry matter loss of hay stored in the barn during 1981 over that of 1980, when the problem was not evident.

Total hay losses were similar to those obtained in 1980-81, with bales not protected from weathering sustaining the greatest losses. Total loss of ryegrass hay covered on racks in 1981 was 15.1 percent compared to 13.8 percent in 1980. The loss figures for barn storage were 5.1 percent and 3.5 percent in 1981 and 1980, respectively.

Laboratory values, changes in quality components, and digestion coefficients for ryegrass hay after 6 months of storage under four different systems during 1981 are shown in Table 7.

Dry matter increased during storage in all hays protected from weathering, while bales stored on the ground and uncovered on racks decreased in dry matter content. Digestible dry matter values of hay stored in the barn and covered on racks were higher ($P<.01$) than those of hay stored on the ground.

Table 6.—Initial bale weight, density, and total percentage shrinkage and losses of ryegrass in large bale package after six months in four storage systems, 1981

Storage method	Initial[1] wt, lbs	Density[1] lbs/ft (3)	Shrinkage[1] 6 mo, %	Losses, %			
				Handling[1]	Dry matter[1]	Refusal[2]	Total
Ground	769	6.64	30.8	8.8	22.8	19.8	51.4
Rock	829	6.04	27.0	5.9	25.9	12.5	44.3
Rock w/cover	865	6.27	14.0	1.1	12.6	1.4	15.1
Barn	895	7.25	17.0	0.0	4.3	0.8	5.1

[1] Each value is a mean of four bales.
[2] Each value from one bale of hay.
[3] Pounds per cubic foot.

Table 7.—Effects of storage conditions over a 6-month period on chemical composition and digestion coefficients of ryegrass hay in large round bales, 1981

Storage system	Composition			
	Initial[1] 4-30-81	Final[1] 10-30-81	Relation to initial	Digestion coefficient
	Dry matter, %			
Ground	89.5	86.5	96.6	47.9b
Rock	88.1	85.7	97.3	49.6ab
Rock w/cover	87.8	91.7	104.4	51.6a
Barn	89.1	90.5	101.1	51.7a
	Neutral-detergent fiber, %			
Ground	63.3	73.0	115.3	60.5^{ns}
Rock	63.8	68.5	107.4	59.9
Rock w/cover	63.4	70.2	110.7	58.2
Barn	63.4	70.2	110.7	62.0
	Hemicellulose, %			
Ground	24.2	26.0	107.4	67.3^{ns}
Rock	23.2	22.1	95.3	66.8
Rock w/cover	21.4	26.3	122.9	68.6
Barn	22.5	26.9	119.6	71.7
	Acid-detergent fiber, %			
Ground	39.1	47.0	120.2	57.2a
Rock	41.1	46.4	112.9	56.2ab
Rock w/cover	42.0	43.9	104.5	52.3b
Barn	40.9	43.2	105.6	55.0ab
	Cellulose, %			
Ground	33.4	37.0	110.8	69.5^{ns}
Rock	34.3	35.1	102.3	66.7
Rock w/cover	35.6	36.1	101.4	65.2
Barn	34.9	36.5	104.6	66.1
	Acid-insoluble lignin, %			
Ground	4.57	8.22	179.9	—
Rock	5.57	9.42	169.1	—
Rock w/cover	5.56	6.51	117.1	—
Barn	5.21	6.16	118.2	—
	Crude protein, %			
Ground	11.0	11.4	103.6	39.6c
Rock	10.9	12.0	110.1	47.0b
Rock w/cover	11.0	10.6	96.4	50.7a
Barn	10.1	10.5	104.0	50.0a
	Available protein, %			
Ground	8.2	5.7	69.5	—
Rock	8.0	6.6	82.5	—
Rock w/cover	8.0	7.0	87.5	—
Barn	7.5	7.6	101.3	—

Continued

Table 7.—Effects of storage conditions over a 6-month period on chemical composition and digestion coefficients of ryegrass hay in large round bales, 1981 (cont'd)

	Composition			
Storage system	Initial[1] 4-30-81	Final[1] 10-30-81	Relation to initial	Digestion coefficient
	In vitro digestible dry matter, %			
Ground	59.4	55.0	92.6	—
Rack	59.0	57.7	97.8	—
Rack w/cover	59.4	58.9	97.6	—
Barn	59.7	59.0	98.8	—

[1] Each value is a mean of four bales of hay.

[a] Values within component sections of digestion coefficient column with different letters differed significantly ($P < .05$).

[ns] Denotes non-significance at ($P < .05$) level.

Neutral-detergent fiber and cellulose increased during storage in all systems. Hemicellulose content increased during storage in all systems but one, uncovered racks. Digestibility of those parameters was not affected by storage mode.

Acid-detergent fiber of ryegrass hay increased during storage in all four systems. However, digestion of ADF was significantly affected only by storage covered on racks compared to storage on the ground. Acid-insoluble lignin of hay also increased during storage. Hay stored on the ground increased 79.9 percent, that on racks uncovered by 69.1 percent, that covered on racks by 17.1 percent, and that in the barn by 18.2 percent. Lignin, an anti-quality component of forage, is considered to be indigestible.

Slight increases in crude protein (CP) content of hay occurred during storage of bales in all modes except covered on racks. Digestibility of CP was reduced significantly, however, where bales were stored without protection from weathering.

Available protein decreased in all hays stored outside. The decrease in AP was greatest in hay stored on the ground, followed by that uncovered on rack. The reductions in AP value were 30.5 percent, 17.5 percent, and 12.5 percent in hay stored on the ground, on exposed racks, and covered on racks, respectively.

Hay stored in all systems was found to have lower *in vitro* digestion values in comparison to initial digestion percentages. The most appreciable decrease in IVDDM occurred in hay that had been stored on the ground.

Summary

Effects of storage method on quantitative and qualitative losses of large, round bales of ryegrass and alfalfa hays were studied in 1980 and 1981. In

1980, ryegrass bales were stored as follows: (1) on an exposed 8-inch gravel bed, (2) directly on the ground, (3) on elevated wooden racks with plastic covering the hay, (4) on elevated wooden racks with hay uncovered, (5) on automobile tires, and, (6) inside a barn. Additionally, in 1980 alfalfa hay was stored in modes 3, 4, and 6. In 1981, ryegrass bales were stored in four of the same modes, omitting storage of bales on gravel and on automobile tires. Losses were determined after 7 and 12 months of storage for ryegrass hay and after 6 and 12 months for alfalfa hay in 1980. For the 1981 crop of ryegrass hay, the losses were measured following 6 months of storage.

Bales of both ryegrass and alfalfa stored in the barn and covered with plastic on elevated wooden racks had minimum shrinkage as well as shape deformation when compared with other storage methods. Ryegrass bales stored on the ground had over 50 percent shrinkage after 12 months of storage. Alfalfa bales showed much lower shrinkage than ryegrass for comparable periods and storage methods.

Ryegrass stored on tires and on the ground showed higher handling losses than that of other storage modes after 12 months. There was no handling loss of hay stored in a barn. Dry matter loss of ryegrass bales stored on the ground approached 40 percent after 12 months of storage, and all other bales not protected from weathering had dry matter losses exceeding 30 percent. Those bales protected from weathering had least animal refusal losses, and bales stored on the ground had highest animal refusal losses.

Total hay loss, a combination of handling, dry matter, and animal refusal, was greater than 50 percent in each year of the 2-year study for ryegrass bales stored outside on the ground. The least total loss occurred in bales protected from weathering.

Moisture content of both alfalfa and ryegrass hay bales increased significantly when not protected from weathering, but bales covered with plastic and those in a barn decreased in moisture content over the storage period.

Structural carbohydrates (NDF, HC, ADF, cellulose) of ryegrass and alfalfa hays were not significantly affected by storage method when measured as a percentage of initial value. However, there were increases in NDF and ADF after 7 and 12 months, irrespective of storage system.

Crude protein (CP) content increased in all bales of all storage systems after 7 and 12 months of storage, but no difference was found among storage modes in CP content as a percent of initial value. Available protein (AP) decreased in weathered bales of ryegrass hay; those bales protected from weathering increased in AP after 7 and 12 months of storage. No difference was shown among storage modes in AP content of alfalfa bales.

In vitro digestible dry matter (IVDDM) of ryegrass hay in exposed storage modes declined, while that of protected hay tended to increase.

There was a significant effect of storage mode on IVDDM of ryegrass hay. The effect was less pronounced in alfalfa hay.

Data from this study show that quality of ryegrass hay in large round bales cannot be preserved if the hay is stored outside without protection from weathering. Outside storage losses can be minimized by storing the bales off the ground on racks and covered with plastic.

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Influence of Soil Reaction and Manganese Applications On Yields and Chemical Composition Of Soybean Plants

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Louisiana Agricultural Experiment Station, Doyle Chambers, Director
Louisiana State University Agricultural Center, Alvin C. Harper, Chancellor

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Influence of Soil Reaction and Manganese Applications on Yields and Chemical Composition of Soybean Plants

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Recent events pertaining to the worldwide energy situation, particularly those relating to a finite supply of natural gas, which is essential to the production of fertilizer-N, have forced a re-evaluation of N management in crop production. Concurrent with this trend has been the necessity to reassess the role of N-fixing species.

One of the leading cash crops in the U.S. is soybeans. The increasing importance of soybeans as a major crop in the South is indicated by the increase of more than four-fold in acreage devoted to soybeans during the past two decades. Soybeans were planted on 6.2 million, 14.4 million, and 27.4 million acres in 1959, 1969, and 1979, respectively (*23, 24, 25*[6]). Although acreage has increased, yields per acre have remained almost constant.

Recent pressures on land usage have forced growers to utilize soils of wider diversity. Manganese (Mn) may range from deficient to excessive on these soils.

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[6] Italic numbers in parentheses refer to Literature Cited, page 42.

The study reported in this publication was a contribution to Project H-1884-R (S-117), "Diagnosis and Correction of Mn and Mo Problems in Legumes."

Review of Literature

Manganese is essential for the growth and reproduction of plants. It is not known to what extent Mn participates in symbiotic N fixation in soybeans, but it is required for the growth of Rhizobia (*26*).

Manganese deficiency of soybeans is commonly reported in the Atlantic Coastal Plain, especially in Virginia and the Carolinas (*11*), and more recently in the Atlantic Flatwood soils of Florida (*18*) and Georgia (*2*), especially on soils with pH values above 6.5. On the other hand, Mn toxicity has been reported in Georgia and Mississippi on well-drained soils with pH levels below 5.5 (*10*, *16*). Also, Mn sufficiency, deficiency, and toxicity levels in soybeans (*6*, *9*, *14*) are undoubtedly influenced by differences among cultivars (*1*, *3*, *4*, *7*).

The complexity of Mn chemistry in soils is well documented and was recently reviewed in considerable detail (*14*). While it is generally accepted that the total soil Mn content bears little relationship to plant uptake, the numerous soil factors that render Mn available for plant use are incompletely understood. Numerous studies have dealt with the influence of organic matter on available Mn (*14*, *17*), the oxidation-reduction potential (*8*), the effect of added fertilizers on native and applied Mn (*15*), and the interaction between Mn and Zn on Mn uptake and translocation (*20*). Add to these the influence of temperature (*22*) and it becomes clear that in addition to natural soil factors, climatic, environmental, and certain management factors must be taken into consideration in attempting to interpret Mn soil tests.

Experimental Procedure

An investigation was initiated in 1976 and continued through 1981 to determine the effects of soil reaction (pH) and five rates of applied Mn on the yield of soybeans (*Glycine max* (L.) Merr.) and on the chemical composition of the soil and the leaves of soybean plants grown on four soils.

The experimental locations, soil types, and initial soil reaction values were: Dean Lee Agricultural Center, Norwood silt loam (Typic Udifluvent), pH 8.1; Red River Valley Experiment Station, Severn very fine sandy loam (Typic Udifluvent), pH 7.8; Macon Ridge Branch Experiment Station, Grenada silt loam (Glossic Fragiudalf), pH 5.9; Perkins Road Agronomy Farm, Falaya silt loam (Aeric Fluvaquent), pH 6.4.

The experimental design at the Dean Lee Agricultural Center and the Red River Valley Experiment Station was a complete randomized block with four replications of each of the five rates of Mn. The experimental design at the Macon Ridge Branch Experiment Station and the Perkins Road Agronomy Farm was a complete randomized block with a split-plot arrangement of treatments. Two levels of S comprised the main plots and the five Mn treatments occupied the subplots. Three replications of each treatment combination were used. The Mn treatments were applied annually from 1976 through 1979. Mn was not applied in 1980 or 1981. Sulfur was applied in 1976, but no S was applied in succeeding years. Soil chemical analysis was used as a guide for P and K fertilization so that these would not become factors limiting the growth of soybeans.

Mn rates were 0, 10, 20, 30, and 40 kg Mn/ha (0, 8.9, 17.8, 26.7, 35.6 lbs. Mn/A) as $MnSO_4 \bullet 3H_2O$, 29 percent Mn. The material was broadcast on the soil surface in an aqueous solution prior to planting. S was applied to the Grenada silt loam at the rates of 0 and 728 kg/ha (650 lbs/A) as sublimed S, 99.8 percent S. Soil testing had shown that 728 kg S/ha would change the pH from 5.9 to 4.5. The S was broadcast on the soil surface and mixed by disking 6 weeks prior to planting in 1976. Similarly, 0 and 1,232 kg S/ha (1,100 lbs/A) were broadcast on the surface of the Falaya silt loam and mixed by disking 12 weeks prior to planting. Soil testing had shown that 1,100 lbs S/A would change the pH from 6.4 to 4.5.

The location, cultivar, and maturity groups of the soybeans were: Dean Lee Agricultural Center—Forrest (Group V), and Bragg (VII); Red River Valley Experiment Station—Centennial (VI), and Bragg (VII); Macon Ridge Branch Experiment Station—Forrest (V), and Bragg (VII); and Perkins Road Agronomy Farm—Lee 74 (VI), and Bragg (VII).

Soil and plant tissue samples were collected from each plot at the R5 stage of development (seeds ⅛-inch long in the pod). The soil samples were air-dried at room temperature, ground to pass through a 2-mm stainless steel sieve, and stored in 16-ounce plastic bags. Soil samples were analyzed for P, K, Ca, Mg, organic matter, and pH by the Soil Testing Laboratory, Louisiana State University. The extractants, soil:solution ratios, and extracting times used in the determination of soil Mn are shown in Table 1. The diethylene triamine pentaacetic acid-triethanolamine

Table 1.—Extractant, soil:extracting solution ratio, extracting time, and reference used for determining soil Mn

Extractant	Soil:extracting solution ratio	Extracting time (min.)	Reference
0.005 M DTPA, 0.1 M TEA, 0.01 M $CaCl_2$, pH 7.3	1:2	120	Lindsay and Narvell, 1969, (12)
H_2O	1:10	30	Sherman and Harmer, 1942, (19)
0.1 N HCL	1:10	60	Sarensen et al., 1971, (21)
0.05 N HCL + 0.025 N H_2SO_4*	1:4	15	Cox, 1968, (6)
0.1 N H_3PO_4	1:10	60	Hoff and Mederski, 1958, (9)
1.5 M $NH_4H_2PO_4$	1:10	60	Haff and Mederski, 1958, (9)

*Double acid.

(DTPA-TEA) extractant was also analyzed for Cu, Zn, and Fe using a Perkin-Elmer 503 atomic absorption spectrophotometer. Extraction of soils with a solution of 0.05 N HCl + 0.025 N H_2SO_4 will be referred to as "double acid" extraction. Extraction with water was discontinued after 1977 because filtration times were longer than practical for routine analysis.

Plant tissue samples were dried at 70°C in a forced-draft oven for 48 hours, ground in a stainless-steel Wiley mill to pass through a 20-mesh screen, and digested in 3:1 v/v mixture of nitric and perchloric acids. Analysis for P followed the vanadate-molybdate-yellow method (5). The Perkin-Elmer 503 atomic absorption spectrophotometer was used to determine tissue concentrations of K, Ca, Mg, Cu, Zn, Fe, and Mn.

Analysis of variance and correlation analysis were used to verify significance of differences among means and of simple correlations, respectively. Values of least significant difference (LSD) reported in Results and Discussion are considered protected. Analyses were performed by the LSU Department of Experimental Statistics, Baton Rouge.

Results and Discussion

The influence of different rates of Mn on the plant and soil chemical analyses and the yields of Forrest and Bragg soybeans grown on Norwood silt loam in 1977, 1978, and 1979 are shown in Tables 2, 3, and 4, respectively. Within cultivars, there were no significant differences among treatments with respect to yield. In 1978, the leaf tissue of the Bragg cultivar from the Mn-treated plots contained a higher concentration of Mn than that from the check plots.

The influence of different Mn rates on the plant and soil chemical analyses and the yields of Centennial and Bragg soybeans grown on Severn very fine sandy loam for 1977, 1978, and 1979, are shown in Tables 5, 6, and 7, respectively. There were no significant differences among Mn treatments with respect to yield. The Norwood silt loam and Severn very fine sandy loam soils have reactions ranging from pH 7.4 to 8.0. Mn availability to the plant was expected to be at such a level as to induce deficiency. However, deficiency symptoms were not observed, even though very low concentrations of DTPA-extractable Mn were found in both soils in 1979.

The influence of different S and Mn rates on the plant and soil chemical analyses and the yield of Forrest and Bragg soybeans grown on Grenada silt loam (1977-79) is shown in Tables 8-13. There were no significant differences among Mn or S treatments with respect to yield during any year. Low yield values were attributed to dry weather in 1978. In 1977 (Tables 8 and 9) and 1978 (Tables 10 and 11), significantly higher concentrations of Mn were found in the tissue of Bragg and Forrest soybean plants in plots receiving S than in plots receiving no S. During early plant development, Mn toxicity symptoms were observed in plots receiving S. The Forrest cultivar tended to become less severely affected as the season progressed than did the Bragg cultivar. In 1977, extractable soil Ca and Mg levels each were lower for plots receiving S than for plots receiving no S. The DTPA-extractable Fe concentration in the soil was higher for plots in which S was applied than for plots in which S was not applied. The concentrations of soil Mn determined by the six methods significantly increased in plots receiving S versus plots receiving no S, with the exception of DTPA-TEA Mn under the Bragg cultivar. In 1978 (Table 10) under Forrest soybeans, there were higher concentrations of Mn extracted from the soil in plots receiving S than in plots receiving no S for all methods. Also, there was a significant difference among Mn treatments with respect to 0.1 *N* HC1-extractable Mn. However, the levels of extractable Mn did not increase as the rates of applied Mn increased. In 1978 (Table 11) under Bragg soybeans, extractable soil Mn was lower in plots receiving S than in plots not receiving S. In 1979 (Table 13) under the Forrest cultivar, there was a significant difference among Mn treatments with respect to plant tissue Mn concentrations. However, the tissue Mn concentration did not increase consistently as the Mn treatment rate increased. In addition, for plots treated with S the concentrations of extractable Ca and Mg each were lower than for plots not treated with S.

The influence of different S and Mn rates on the plant and soil chemical analyses and the yields of Bragg and Lee 74 soybeans grown on Falaya silt loam (1977-79) is shown in Tables 14-19. In 1977 (Table 14) the yield of Bragg soybeans was approximately 4 bu/A higher for plots not receiving S than for plots receiving S, but Mn treatments had no significant effect on yield. The data show that there were no significant differences among S or Mn treatments with respect to yield for any of the remaining cultivar-year combinations. It should be noted that during periods of high rainfall, early in the growing season, in poorly drained areas of the field, Mn toxicity symptoms appeared in the Bragg cultivar. The field appeared to be adequately drained for the Lee 74 cultivar.

Leaf tissue analysis of the Bragg cultivar in 1977 (Table 14) showed a significant increase in K concentration and a significant decrease in Ca concentration with the application of S. This trend was not determined for the Lee 74 variety (Table 15). In 1977, the tissue concentrations of Mn in both the Lee 74 and Bragg soybeans were higher for plots receiving S than for plots not receiving S, while Mn applications had no similar effect. Soil analysis showed a significant decrease in extractable Ca and Mg for plots receiving S versus plots not receiving S. Also, the concentrations of DTPA-extractable Mn and Fe increased for plots receiving S versus plots receiving no S.

Table 2. —Influence of different rates of Mn on plant and soil chemical analyses and yields of Forrest and Bragg soybeans grown on Norwood silt loam, Dean Lee Agricultural Center, Alexandria, La., 1977

	Mn treatments, lbs./acre													
	0		8.9		17.8		26.8		35.7		$LSD_{.05}$		C.V.%	
Item	Forrest	Bragg	Forrest	Bragg	Forrest	Bragg	Forrest	Bragg	Forrest	Bragg	Forrest	Bragg	Forrest	Bragg
Yield, bu/acre	38.3	35.5	39.1	33.6	38.2	33.5	39.3	33.2	37.9	33.2	NS	NS	4.6	5.5
Plant analysis														
P, %	0.24	0.24	0.23	0.24	0.24	0.22	0.23	0.23	0.25	0.21	NS	NS	4.8	8.7
K, %	1.45	1.28	1.39	1.24	1.41	1.09	1.36	1.18	1.51	1.11	NS	NS	5.6	10.1
Ca, %	0.88	1.30	0.91	1.26	0.90	1.38	0.93	1.32	0.84	1.37	NS	NS	9.0	9.1
Mg, %	0.35	0.43	0.35	0.45	0.36	0.44	0.36	0.44	0.36	0.46	NS	NS	6.6	6.6
Cu, ppm	12.3	15.5	11.8	15.0	11.5	14.5	12.3	15.3	11.8	15.3	NS	NS	6.9	4.2
Zn, ppm	48.3	53.0	49.0	50.8	48.0	54.3	49.5	53.8	44.8	56.3	NS	NS	4.9	6.8
Fe, ppm	88.5	117.3	87.0	115.8	86.8	119.0	83.0	113.3	83.8	113.0	NS	NS	5.2	5.7
Mn, ppm	71.5	93.0	70.8	89.3	67.0	98.3	70.8	100.3	66.5	103.5	NS	NS	9.3	8.6
Soil analysis														
Mn,[1] ppm	5.9	4.5	6.0	5.5	6.0	5.0	6.0	5.4	5.9	5.1	NS	NS	5.2	8.2
Mn,[2] ppm	11.9	8.3	11.6	7.5	10.8	6.9	11.4	8.5	10.0	7.2	NS	NS	19.8	40.8
Mn,[3] ppm	90.5	91.8	92.3	97.8	90.8	99.5	98.0	96.8	94.8	95.8	NS	NS	4.1	4.3
Mn,[4] ppm	17.7	13.7	17.7	13.8	16.5	13.1	17.8	14.2	16.8	13.8	NS	NS	11.4	25.2
Mn,[5] ppm	57.5	61.0	57.0	61.5	58.0	62.5	61.0	61.0	58.0	62.0	NS	NS	8.8	6.8
Mn,[6] ppm	0.33	0.18	0.28	0.23	0.23	0.18	0.25	0.10	0.23	0.28	NS	NS	37.2	69.3
pH	8.0	8.1	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	—	—	—	—
O.M., %	0.73	0.71	0.72	0.78	0.75	0.73	0.74	0.77	0.72	0.70	NS	NS	12.3	6.6
P, ppm	212	214	218	211	202	204	207	197	208	207	NS	NS	8.8	8.1
K, ppm	85.8	82.5	87.8	80.5	91.5	83.0	87.8	81.3	83.0	83.3	NS	NS	13.6	7.2
Ca, ppm	3766.0	4032.0	3950.0	4079.0	3906.0	4175.0	3968.0	4035.0	3956.0	4098.0	NS	NS	2.6	3.8
Mg, ppm	326.0	311.0	321.0	314.0	339.0	318.0	331.0	311.0	339.0	308.0	NS	NS	6.6	7.8
Cu,[1] ppm	0.64	0.89	0.67	1.15	0.68	0.87	0.65	0.95	0.60	0.94	NS	0.15	15.0	10.0
Zn,[1] ppm	0.32	0.33	0.35	0.36	0.38	0.30	0.37	0.33	0.33	0.36	NS	NS	12.4	12.3
Fe,[1] ppm	5.2	4.2	5.3	5.6	5.4	5.5	5.0	5.6	5.4	7.3	NS	NS	13.7	37.4

[1] DTPA-TEA. [2] 0.05 N HCl in 0.025 N H_2SO_4. [3] 0.1 N HCl. [4] 0.1 N H_3PO_4. [5] 1.5 M $NH_4H_2PO_4$. [6] H_2O.

Table 3. —Influence of different rates of Mn on plant and soil chemical analyses and yields of Forrest and Bragg soybeans grown on Norwood silt loam, Dean Lee Agricultural Center, Alexandria, La., 1978

Item	Mn treatments, lbs./acre										LSD$_{.05}$		C.V.%	
	0		8.9		17.8		26.8		35.7					
	Farrest	Bragg	Farrest	Bragg	Farrest	Bragg	Farrest	Bragg	Farrest	Bragg	Farrest	Bragg	Farrest	Bragg
Yield, bu/acre	44.2	36.5	41.5	37.2	42.1	35.5	41.1	38.2	41.2	34.3	NS	NS	4.4	12.7
Plant analysis														
P, %	0.21	0.22	0.20	0.22	0.23	0.22	0.21	0.25	0.18	0.24	NS	NS	14.1	7.2
K, %	0.90	1.21	0.87	1.29	0.91	1.24	0.94	1.41	0.91	1.38	NS	NS	6.9	8.9
Ca, %	1.54	1.19	1.51	1.18	1.45	1.20	1.51	1.19	1.40	1.20	NS	NS	8.0	7.6
Mg, %	0.48	0.45	0.48	0.49	0.46	0.48	0.46	0.49	0.46	0.50	NS	NS	9.2	7.4
Cu, ppm	17.8	17.3	16.0	19.4	16.8	19.0	17.4	19.0	17.1	20.5	NS	1.9	9.0	6.8
Zn, ppm	41.8	35.9	42.5	38.0	42.5	35.6	41.9	37.3	40.1	38.1	NS	NS	11.0	10.9
Fe, ppm	123.8	142.5	118.8	143.8	116.3	148.8	118.8	148.8	115.0	156.3	NS	NS	6.2	5.8
Mn, ppm	133.8	110.3	141.0	119.5	145.0	126.0	145.5	127.8	138.3	133.5	NS	9.5	6.7	5.1
Soil analysis														
Mn,[1] ppm	12.0	12.5	13.2	12.9	12.6	14.3	13.2	15.0	13.8	14.0	NS	NS	7.3	12.7
Mn,[2] ppm	36.7	30.9	36.6	30.9	33.4	33.7	37.2	31.3	38.3	30.9	NS	NS	6.9	17.2
Mn,[3] ppm	91.1	84.0	99.6	94.7	101.2	97.8	116.5	97.4	109.2	93.9	NS	NS	19.1	18.3
Mn,[4] ppm	41.3	36.5	36.8	36.5	36.3	36.5	32.8	35.8	36.3	32.8	NS	NS	15.8	21.3
Mn,[5] ppm	26.5	32.0	38.5	31.0	33.5	33.5	32.5	30.5	37.5	31.5	NS	NS	28.2	19.2
pH	7.9	8.0	7.9	7.9	8.0	7.9	8.0	7.9	8.0	7.9	—	—	—	—
O.M., %	0.83	0.86	0.72	0.85	0.74	0.84	0.76	0.86	0.66	0.87	NS	NS	12.1	23.2
P, ppm	199.0	185.0	188.0	186.0	190.0	208.0	201.0	173.0	181.0	171.0	NS	NS	13.8	11.6
K, ppm	74.0	75.0	69.0	66.0	73.0	72.0	77.0	72.0	67.0	75.0	NS	NS	16.9	14.0
Ca, ppm	3440.0	3570.0	3462.0	3629.0	3460.0	3618.0	3461.0	3585.0	3535.0	3614.0	NS	NS	2.3	3.5
Mg, ppm	251.0	252.0	251.0	257.0	262.0	257.0	257.0	252.0	268.0	247.0	NS	NS	5.9	8.9
Cu,[1] ppm	1.93	2.11	1.88	1.93	1.72	2.02	1.56	2.45	1.91	2.11	NS	NS	13.0	19.6
Zn,[1] ppm	0.55	0.60	0.59	0.59	0.56	0.63	0.53	0.70	0.55	0.64	NS	NS	10.2	13.1
Fe,[1] ppm	7.55	6.40	5.75	5.80	7.05	6.65	7.30	5.50	5.70	5.50	NS	NS	18.1	17.8

[1] DTPA-TEA. [2] 0.05 N HCl in 0.025 N H_2SO_4. [3] 0.1 N HCl. [4] 0.1 N H_3PO_4.

Table 4.—Influence of different rates of Mn on plant and soil chemical analyses and yields of Forrest and Bragg soybeans grown on Norwood silt loam, Dean Lee Agricultural Center, Alexandria, La., 1979

	Mn treatments, lbs./acre													
	0		8.9		17.8		26.8		35.7		LSD$_{.05}$		C.V.%	
Item	Farrest	Bragg	Farrest	Bragg	Farrest	Bragg	Farrest	Bragg	Farrest	Bragg	Farrest	Bragg	Farrest	Bragg
Yield, bu/acre	42.3	37.6	42.6	39.4	42.4	38.6	42.7	35.0	40.9	35.0	NS	NS	5.6	9.8
Plant analysis														
P, %	0.18	0.20	0.18	0.20	0.19	0.21	0.19	0.19	0.19	0.20	NS	NS	6.6	8.2
K, %	0.93	1.08	0.88	1.13	0.88	1.13	0.90	0.98	0.93	1.05	NS	NS	6.3	6.6
Ca, %	1.30	1.03	1.38	1.01	1.29	1.05	1.29	1.04	1.21	1.00	NS	NS	7.7	8.4
Mg, %	0.43	0.40	0.44	0.41	0.42	0.42	0.41	0.40	0.42	0.40	NS	NS	9.2	4.8
Cu, ppm	13.3	11.3	12.9	11.1	12.5	11.1	13.2	11.0	12.5	11.0	NS	NS	5.7	8.2
Zn, ppm	70.6	54.3	73.0	53.8	66.0	52.0	71.8	52.1	68.6	51.1	NS	NS	9.3	6.5
Fe, ppm	120.8	139.5	116.5	168.0	113.0	146.0	117.3	152.5	112.8	129.0	NS	NS	11.5	27.2
Mn, ppm	205.0	148.8	216.3	146.3	210.0	152.5	191.3	156.3	210.0	152.5	NS	NS	15.2	6.2
Sail analysis														
Mn,[1] ppm	3.4	3.5	3.2	4.2	3.6	4.1	4.0	4.3	4.1	4.0	NS	NS	13.8	16.8
Mn,[2] ppm	61.6	59.9	63.4	63.6	59.5	65.7	67.1	65.9	65.2	60.5	NS	NS	12.2	10.1
Mn,[3] ppm	142.8	146.0	140.3	150.0	144.3	155.0	148.5	153.5	142.3	151.8	NS	NS	3.3	5.8
Mn,[4] ppm	76.3	73.8	75.5	79.8	76.8	79.8	78.5	83.3	77.8	77.5	NS	NS	3.3	4.9
Mn,[5] ppm	64.0	62.8	56.3	70.5	58.5	70.8	55.5	66.0	60.0	72.5	NS	NS	16.5	13.3
pH	7.8	7.9	7.9	7.8	7.8	7.8	7.9	7.9	7.9	7.8	—	—	—	—
O.M., %	0.81	0.93	0.80	0.89	0.87	0.88	0.90	0.89	0.84	0.87	0.07	NS	5.1	8.8
P, ppm	172.0	169.0	174.0	177.0	173.0	169.0	181.0	182.0	182.0	164.0	NS	NS	6.8	8.3
K, ppm	88.0	96.0	86.0	99.0	90.0	96.0	87.0	101.0	78.0	99.8	NS	NS	10.2	16.5
Ca, ppm	3537.0	3774.0	3737.0	3754.0	3754.0	3877.0	3733.0	3794.0	3757.0	3606.0	NS	NS	3.4	5.6
Mg, ppm	296.0	301.0	278.0	268.0	288.0	287.0	279.0	287.0	307.0	287.0	NS	NS	7.2	12.1
Cu,[1] ppm	1.55	1.56	1.62	1.44	1.63	1.39	1.59	1.57	1.61	1.39	NS	0.14	9.0	6.3
Zn,[1] ppm	0.40	0.51	0.45	0.43	0.46	0.43	0.46	0.54	0.42	0.42	NS	NS	13.0	16.5
Fe,[1] ppm	3.01	1.82	1.77	1.71	1.94	1.74	1.79	1.90	2.92	1.65	NS	NS	67.4	11.8

[1] DTPA-TEA. [2] 0.05 N HCl in 0.025 N H_2SO_4. [3] 0.1 N HCl. [4] 0.1 N H_3PO_4. [5] 1.5 M $NH_4H_2PO_4$.

Table 5. —Influence of different rates of Mn on plant and soil chemical analyses and yields of Centennial and Bragg soybeans grown on Severn very fine sandy loam, Red River Valley Experiment Station, Bossier City, La., 1977

	Mn treatments, lbs./acre										LSD $_{.05}$		C.V.%	
	0		8.9		17.8		26.8		35.7					
Item	Cent.[1]	Bragg	Cent.	Bragg	Cent.	Bragg	Cent.	Bragg	Cent.	Bragg	Cent.	Bragg	Cent.	Bragg
Yield, bu/acre	39.4	44.5	42.3	47.5	42.2	44.3	38.4	43.7	37.7	44.6	NS	NS	9.1	6.0
Plant analysis														
P, %	0.25	0.25	0.25	0.26	0.26	0.24	0.23	0.25	0.24	0.25	NS	NS	5.0	8.8
K, %	1.63	1.31	1.66	1.31	1.84	1.31	1.64	1.37	1.77	1.32	NS	NS	9.2	9.0
Ca, %	0.75	1.12	0.73	1.09	0.75	1.08	0.76	1.07	0.69	1.08	NS	NS	8.7	5.7
Mg, %	0.41	0.47	0.39	0.47	0.39	0.46	0.40	0.45	0.39	0.46	NS	NS	3.6	4.2
Cu, ppm	13.3	15.3	14.0	16.0	14.5	15.0	12.5	15.5	13.5	15.5	NS	NS	6.5	7.0
Zn, ppm	82.0	68.3	81.8	67.8	79.0	67.8	78.8	69.3	78.0	68.0	NS	NS	6.4	6.0
Fe, ppm	163.8	134.5	144.5	136.3	170.8	128.3	163.5	128.5	164.3	123.5	NS	NS	11.1	9.3
Mn, ppm	48.5	56.5	49.5	55.3	48.3	53.3	46.3	54.8	47.0	54.8	NS	NS	5.3	6.2
Soil Analysis														
Mn,[2] ppm	5.5	4.2	5.7	5.2	6.1	4.9	5.6	5.4	6.0	5.3	0.18	0.59	2.1	8.0
Mn,[3] ppm	24.3	24.3	23.8	23.5	26.3	21.5	24.0	26.5	25.0	26.0	NS	NS	6.2	9.2
Mn,[4] ppm	49.5	47.0	51.5	48.5	57.3	46.5	52.8	50.0	52.3	48.5	3.7	NS	4.7	4.5
Mn,[5] ppm	18.5	19.2	19.9	19.7	20.5	18.8	18.7	21.1	19.5	20.4	NS	1.3	5.1	4.3
Mn,[6] ppm	34.5	36.5	40.0	40.5	40.0	42.0	39.0	43.0	39.5	42.0	NS	NS	9.2	15.2
Mn,[7] ppm	0.28	0.38	0.35	0.50	0.30	0.45	0.28	0.45	0.28	0.50	NS	NS	45.2	27.9
pH	7.9	7.8	7.9	7.7	7.8	7.6	7.8	7.7	7.8	7.8	—	—	—	—
O.M., %	0.72	0.67	0.70	0.68	0.76	0.64	0.69	0.63	0.70	0.64	NS	NS	7.6	9.2
P, ppm	126.3	120.5	124.5	130.0	140.8	119.0	135.0	114.8	130.3	119.8	NS	NS	10.0	10.2
K, ppm	98.0	97.3	97.0	97.3	101.3	95.5	107.5	82.8	100.8	86.8	NS	NS	10.5	9.6
Ca, ppm	1785.0	1365.0	1695.0	1310.0	1678.0	1251.0	1911.0	1273.0	1800.0	1284.0	NS	NS	10.7	15.1
Mg, ppm	374.0	298.0	359.0	302.0	358.0	298.0	405.0	283.0	377.0	295.0	NS	NS	7.6	11.8
Cu,[2] ppm	0.91	0.82	0.86	0.76	0.98	0.70	0.88	0.70	0.91	0.68	NS	NS	9.7	10.9
Zn,[2] ppm	0.35	0.42	0.31	0.45	0.39	0.44	0.31	0.32	0.35	0.30	NS	NS	13.6	43.3
Fe,[2] ppm	6.4	5.7	5.6	6.9	6.4	5.4	7.2	6.0	6.5	6.2	NS	NS	21.6	14.9

[1] Centennial (Cent.). [2] DTPA-TEA. [3] 0.05 N HCl in 0.025 N H_2SO_4. [4] 0.1 N HCl. [5] 0.1 N H_3PO_4. [6] 1.5 M $NH_4H_2PO_4$. [7] H_2O.

Table 6. —Influence of different rates of Mn on plant and soil chemical analyses and yields of Centennial and Bragg soybeans grown on Severn very fine sandy loam, Red River Valley Experiment Station, Bossier City, La., 1978

	Mn treatments, lbs./acre													
	0		8.9		17.8		26.8		35.7		LSD$_{.05}$		C.V.%	
Item	Cent.[1]	Bragg	Cent.	Bragg	Cent.	Bragg	Cent.	Bragg	Cent.	Bragg	Cent.	Bragg	Cent.	Bragg
Yield, bu/acre	26.2	37.7	31.1	42.4	34.1	39.1	29.6	38.4	32.1	38.5	NS	NS	16.9	19.3
Plant analysis														
P, %	0.20	0.23	0.19	0.26	0.19	0.25	0.20	0.23	0.19	0.25	NS	NS	5.2	8.0
K, %	1.40	1.74	1.40	1.78	1.46	1.80	1.46	1.60	1.50	1.81	NS	NS	5.7	12.3
Ca, %	1.17	0.91	1.18	0.97	1.07	0.83	1.06	0.98	1.06	0.84	NS	NS	13.5	19.2
Mg, %	0.62	0.48	0.64	0.52	0.63	0.46	0.58	0.51	0.59	0.47	NS	NS	11.4	11.0
Cu, ppm	18.3	20.8	18.3	19.9	19.9	18.0	18.0	19.8	19.4	18.6	NS	NS	8.7	9.8
Zn, ppm	71.4	55.3	72.5	52.8	70.3	47.4	67.6	53.6	69.6	49.4	NS	NS	7.2	15.5
Fe, ppm	177.5	223.8	162.5	213.8	175.0	218.8	178.8	236.3	160.0	191.3	NS	NS	6.0	28.1
Mn, ppm	63.0	61.3	62.8	63.5	67.3	60.3	64.5	61.8	65.3	55.5	NS	NS	4.6	12.1
Soil analysis														
Mn,[2] ppm	12.9	11.9	12.4	12.7	12.9	14.1	12.5	14.2	14.3	13.9	NS	NS	10.7	10.8
Mn,[3] ppm	34.1	34.6	36.2	35.9	38.4	36.5	36.9	37.0	38.3	36.2	2.7	NS	4.9	7.1
Mn,[4] ppm	72.3	68.3	73.3	67.0	77.0	68.8	76.0	70.3	76.8	73.0	NS	NS	5.7	5.2
Mn,[5] ppm	31.8	33.6	35.1	34.3	36.8	36.2	34.4	37.0	37.5	37.3	3.6	2.7	6.8	5.0
Mn,[6] ppm	33.0	33.0	30.0	30.0	47.0	47.0	37.0	37.0	34.5	34.5	NS	NS	21.5	21.5
pH	7.8	7.7	7.8	7.7	7.8	7.7	7.7	7.7	7.7	7.7	—	—	—	—
O.M., %	0.80	0.70	0.74	0.74	0.76	0.69	0.71	0.69	0.69	0.73	NS	NS	7.2	11.9
P, ppm	109.5	117.8	111.5	137.0	113.8	127.3	120.8	143.0	113.8	141.0	NS	15.5	5.7	7.8
K, ppm	85.5	98.3	87.5	94.3	95.0	100.3	96.0	85.8	88.3	88.3	NS	NS	13.8	11.9
Ca, ppm	1471.0	1153.0	1406.0	1153.0	1479.0	1189.0	1531.0	1203.0	1463.0	1159.0	NS	NS	8.8	13.6
Mg, ppm	340.0	293.0	324.0	260.0	373.0	275.0	368.0	272.0	350.0	279.0	NS	NS	8.5	12.6
Cu,[2] ppm	2.17	2.23	1.71	2.31	1.56	2.20	1.66	1.74	2.01	1.68	NS	NS	20.7	39.6
Zn,[2] ppm	1.08	0.86	0.70	0.71	0.84	0.83	0.81	0.66	0.87	0.64	NS	NS	21.4	37.4
Fe,[2] ppm	5.85	6.25	6.25	6.15	6.20	6.65	6.55	6.20	6.20	6.40	NS	NS	10.4	13.0

[1] Centennial (Cent.). [2] DTPA-TEA. [3] 0.05 N HCl in 0.025 N H_2SO_4. [4] 0.1 N HCl. [5] 0.1 N H_3PO_4. [6] 1.5 M $NH_4H_2PO_4$.

Table 7.—Influence of different rates of Mn on plant and soil chemical analyses and yields of Centennial and Bragg soybeans grown on Severn very fine sandy loam, Red River Valley Experiment Station, Bossier City, La., 1979

Item	Mn treatments, lbs./acre										LSD $_{.05}$		C.V.%	
	0		8.9		17.8		26.8		35.7					
	Cent.[1]	Bragg	Cent.	Bragg	Cent.	Bragg	Cent.	Bragg	Cent.	Bragg	Cent.	Bragg	Cent.	Bragg
Yield, bu/acre	47.7	48.0	50.3	46.9	48.8	45.4	47.4	43.5	50.4	47.3	NS	NS	5.7	13.0
Plant analysis														
P, %	0.24	0.24	0.24	0.26	0.24	0.24	0.24	0.24	0.30	0.23	NS	NS	16.9	11.0
K, %	1.56	1.59	1.59	1.69	1.60	1.55	1.60	1.59	1.88	1.41	NS	NS	20.1	12.0
Ca, %	1.08	1.19	1.09	1.14	1.13	1.21	1.15	1.34	1.25	1.23	NS	NS	15.3	4.8
Mg, %	0.40	0.44	0.38	0.42	0.39	0.43	0.41	0.43	0.47	0.45	NS	NS	14.9	6.6
Cu, ppm	13.3	14.8	12.8	14.6	12.6	14.4	13.4	13.9	15.8	15.4	NS	NS	19.8	6.7
Zn, ppm	86.9	64.9	84.5	63.6	84.9	68.5	87.4	70.6	88.3	76.4	NS	NS	7.4	9.8
Fe, ppm	116.8	149.0	112.3	130.3	118.8	152.0	126.3	130.5	135.0	153.8	NS	NS	16.0	12.2
Mn, ppm	70.0	87.5	71.3	78.8	76.3	86.3	83.8	81.3	91.3	97.5	NS	NS	17.2	12.7
Soil analysis														
Mn,[2] ppm	1.4	4.6	1.6	4.6	1.5	4.6	1.6	5.1	1.6	4.8	NS	NS	22.7	10.3
Mn,[3] ppm	44.8	43.0	43.7	38.4	46.8	41.8	47.9	45.4	45.8	41.3	NS	NS	9.0	14.7
Mn,[4] ppm	68.5	69.8	68.5	67.0	73.5	62.8	78.0	71.3	76.0	69.0	NS	NS	6.8	11.9
Mn,[5] ppm	42.8	42.8	43.0	41.5	43.3	43.0	46.0	47.5	45.8	45.3	NS	NS	6.5	8.3
Mn,[6] ppm	39.0	36.8	33.0	37.5	41.0	38.3	44.3	39.3	35.5	41.5	NS	NS	14.0	6.2
pH	7.4	7.5	7.5	7.6	7.6	7.5	7.7	7.7	7.6	7.7	—	—	—	—
O.M., %	0.60	0.66	0.57	0.67	0.69	0.65	0.73	0.65	0.72	0.73	0.1	NS	29.6	11.8
P, ppm	132.8	137.3	132.5	134.8	142.5	140.3	139.3	126.3	137.5	123.5	NS	NS	4.3	8.0
K, ppm	85.3	94.5	84.0	93.3	93.5	98.3	100.3	87.0	98.5	89.3	12.2	NS	8.8	10.7
Ca, ppm	1406.0	1203.0	1347.0	1076.0	1430.0	1139.0	1547.0	1105.0	1466.0	1134.0	NS	NS	9.9	18.0
Mg, ppm	394.0	328.0	370.0	305.0	390.0	323.0	426.0	312.0	404.0	327.0	NS	NS	7.8	15.0
Cu,[2] ppm	1.06	0.84	1.18	0.76	1.06	1.64	1.67	0.72	1.08	0.77	NS	NS	44.3	73.8
Zn,[2] ppm	0.37	0.48	0.43	0.54	0.39	0.70	0.43	0.41	0.37	0.39	NS	NS	26.7	42.6
Fe,[2] ppm	2.03	8.36	1.67	7.02	2.15	8.25	1.88	7.14	1.84	7.20	NS	NS	12.0	12.6

[1] Centennial (Cent.).
[2] DTPA-TEA.
[3] 0.05 N HCl in 0.025 N H_2SO_4.
[4] 0.1 N HCl.
[5] 0.1 N H_3PO_4.
[6] 1.5 M $NH_4H_2PO_4$.

Table 8.—Influence of applications of S and different rates of Mn on plant and soil chemical analyses and yield of Forrest soybeans grown on Grenada silt loam, Macon Ridge Experiment Station, Winnsboro, La., 1977

	S treatments												
	No S					S							
	Mn treatments, lbs./acre					Mn treatments, lbs./acre					S	Mn	
Item	0	8.9	17.8	26.8	35.7	0	8.9	17.8	26.8	35.7	LSD$_{.05}$	LSD$_{.05}$	C.V.%
Yield, bu/acre	18.3	16.6	18.0	18.5	20.0	15.1	16.2	14.3	16.3	17.5	NS	NS	12.3
Plant analysis													
P, %	0.31	0.31	0.29	0.30	0.31	0.29	0.28	0.29	0.29	0.28	0.01	NS	4.4
K, %	1.42	1.47	1.30	1.40	1.26	1.41	1.35	1.35	1.31	1.29	NS	NS	11.1
Ca, %	0.83	0.79	0.98	0.81	0.82	0.74	0.77	0.82	0.85	0.85	NS	0.08	8.3
Mg, %	0.46	0.46	0.51	0.45	0.47	0.46	0.44	0.46	0.48	0.50	NS	NS	11.4
Cu, ppm	9.3	10.0	9.0	9.3	8.3	9.3	8.3	8.7	10.0	8.3	NS	NS	13.0
Zn, ppm	45.0	49.3	43.0	41.7	41.7	50.0	47.7	52.3	50.7	49.0	3.0	3.0	8.1
Fe, ppm	96.3	92.0	91.0	95.7	87.0	81.7	77.3	78.3	87.7	91.3	NS	NS	9.2
Mn, ppm	204.7	182.3	194.0	183.0	193.0	402.3	450.3	401.3	561.0	478.0	237	NS	26.8
Soil analysis													
Mn,[1] ppm	84.7	90.3	98.7	103.0	94.0	138.3	120.0	126.3	141.0	145.0	20	NS	16.5
Mn,[2] ppm	57.3	63.0	63.3	65.0	59.0	93.3	86.3	93.3	98.0	105.0	9	NS	20.1
Mn,[3] ppm	95.3	98.0	105.7	109.0	98.0	142.3	123.3	134.3	143.0	152.0	10	NS	15.2
Mn,[4] ppm	63.3	67.0	69.7	70.0	66.0	95.3	86.0	93.3	102.0	106.0	7	NS	18.6
Mn,[5] ppm	83.0	78.7	88.0	81.0	76.0	106.0	99.0	111.0	124.0	106.0	11	NS	23.3
Mn,[6] ppm	1.57	1.40	1.83	1.77	1.73	4.20	3.63	3.50	6.73	5.27	1.51	NS	61.5
pH	5.3	5.2	5.3	5.3	5.4	4.9	4.9	4.9	5.0	4.9	—	—	—
O.M., %	0.79	0.79	0.80	0.82	0.77	0.77	0.69	0.80	0.74	0.72	NS	NS	6.3
P, ppm	67.7	80.3	72.7	86.0	74.3	76.3	75.0	82.7	66.0	75.0	NS	NS	11.6
K, ppm	111.7	135.0	92.7	126.0	111.3	99.7	103.0	128.0	100.3	98.0	NS	NS	20.0
Ca, ppm	640.0	597.0	640.0	630.0	670.0	453.0	470.0	480.0	507.0	483.0	66	NS	15.8
Mg, ppm	131.0	122.0	139.0	132.0	146.0	104.0	115.0	111.0	115.0	104.0	18	NS	18.3
Cu,[1] ppm	0.55	0.63	0.50	0.59	0.59	0.57	0.52	0.55	0.62	0.56	NS	NS	10.8
Zn,[1] ppm	0.37	0.53	0.36	0.43	0.35	0.44	0.39	0.55	0.44	0.39	NS	NS	22.1
Fe,[1] ppm	27.3	32.3	29.7	30.0	29.7	38.0	35.7	37.3	34.7	35.0	2.0	NS	10.0

[1] DTPA-TEA. [2] 0.05 N HCl in 0.[illegible] N H_2SO_4. [3] 0.1 N HCl. [4] 0.1 N H_3PO_4. [5] 1.5 M NH_4H_2[illegible]$_4$. [6] H_2O.

Table 9. —Influence of applications of S and different rates of Mn on plant and soil chemical analyses and yield of Bragg soybeans grown on Grenada silt loam, Macon Ridge Experiment Station, Winnsboro, La., 1977

	S treatments												
	No S					S							
	Mn treatments, lbs./acre					Mn treatments, lbs./acre					S	Mn	
Item	0	8.9	17.8	26.8	35.7	0	8.9	17.8	26.8	35.7	$LSD_{.05}$	$LSD_{.05}$	C.V.%
Yield, bu/acre	12.1	14.5	14.0	14.2	12.8	11.6	13.7	12.2	12.0	10.2	NS	NS	21.9
Plant analysis													
P, %	0.36	0.38	0.36	0.37	0.36	0.35	0.34	0.37	0.36	0.34	NS	NS	4.4
K, %	1.74	1.91	1.80	1.84	1.86	1.83	1.74	1.89	1.83	1.71	NS	NS	6.8
Ca, %	0.78	0.67	0.75	0.73	0.77	0.73	0.77	0.71	0.74	0.75	NS	NS	7.8
Mg, %	0.46	0.45	0.48	0.45	0.48	0.45	0.46	0.43	0.44	0.43	NS	NS	6.8
Cu, ppm	13.0	14.7	12.7	13.0	12.3	14.0	14.0	13.7	13.3	13.0	NS	0.8	4.6
Zn, ppm	44.0	48.0	44.0	42.3	43.3	50.0	50.0	51.0	50.3	51.0	NS	NS	10.2
Fe, ppm	106.3	102.0	105.0	106.3	105.3	108.3	107.0	100.7	98.0	98.7	NS	NS	6.0
Mn, ppm	154.7	250.0	194.3	175.0	244.0	486.7	447.3	445.0	423.3	449.3	162	NS	40.9
Soil analysis													
Mn,[1] ppm	88.0	98.7	100.0	100.3	90.0	136.3	132.3	133.0	125.0	128.7	NS	NS	24.3
Mn,[2] ppm	55.0	69.3	72.3	67.0	59.3	99.7	95.0	94.3	95.0	92.0	20	NS	26.8
Mn,[3] ppm	100.3	114.3	119.3	122.0	109.0	161.3	152.0	150.3	144.0	149.0	31	NS	20.6
Mn,[4] ppm	59.3	76.0	75.0	74.0	65.0	100.0	99.0	99.3	98.3	95.3	19	NS	26.5
Mn,[5] ppm	64.0	85.0	84.7	78.0	73.0	115.0	109.0	111.0	111.0	109.0	12	NS	21.6
Mn,[6] ppm	0.73	0.73	2.33	1.33	1.70	5.77	5.57	3.47	4.07	3.67	1.83	NS	78.1
pH	5.5	5.3	5.4	5.5	5.4	5.0	5.1	5.0	5.0	5.1	—	—	—
O.M., %	0.90	0.96	0.90	0.84	0.79	0.95	0.98	0.98	0.96	0.90	NS	.08	7.4
P, ppm	97.0	113.0	99.0	101.0	93.3	108.0	100.3	102.3	101.3	100.3	NS	NS	6.8
K, ppm	105.7	123.7	106.7	110.7	100.3	102.0	109.7	120.7	99.0	89.3	NS	NS	14.4
Ca, ppm	773.0	660.0	763.0	773.0	773.0	513.0	593.0	550.0	556.0	590.0	163	NS	16.1
Mg, ppm	168.0	156.0	188.0	173.0	180.0	137.0	148.0	130.0	135.0	159.0	29	NS	22.4
Cu,[1] ppm	0.65	0.59	0.58	0.63	0.60	0.65	0.74	0.85	0.55	0.57	NS	NS	15.9
Zn,[1] ppm	0.38	0.52	0.39	0.43	0.39	0.47	0.54	0.50	0.44	0.43	NS	NS	26.9
Fe,[1] ppm	27.7	31.3	26.7	28.3	29.0	36.7	34.0	34.7	32.3	31.3	3.3	NS	13.7

[1] DTPA-TEA.

[2] 0.05 N HCl in 0.025 N H_2SO_4.

[3] 0.1 N HCl.

[4] 0.1 N H_3PO_4.

[5] 1.5 M $NH_4H_2PO_4$.

[6] H_2O.

Table 10. —Influence of applications of S and different rates of Mn on plant and soil chemical analyses and yield of Forrest soybeans grown on Grenada silt loam, Macon Ridge Experiment Station, Winnsboro, La., 1978

	S treatments												
	No S					S							
	Mn treatments, lbs./acre					Mn treatments, lbs./acre					S	Mn	
Item	0	8.9	17.8	26.8	35.7	0	8.9	17.8	26.8	35.7	$LSD_{.05}$	$LSD_{.05}$	C.V.%
Yield, bu/acre	7.9	6.4	7.1	10.8	8.3	4.3	7.3	4.9	7.6	8.0	NS	NS	27.5
Plant analysis													
P, %	0.18	0.17	0.20	0.18	0.18	0.18	0.17	0.17	0.18	0.17	NS	NS	6.3
K, %	0.85	0.95	0.77	0.92	0.68	0.85	0.68	0.82	0.70	0.70	NS	NS	24.8
Ca, %	1.43	1.38	1.40	1.47	1.43	1.40	1.43	1.55	1.62	1.57	NS	NS	7.4
Mg, %	0.43	0.40	0.45	0.40	0.45	0.43	0.45	0.47	0.47	0.47	NS	NS	9.7
Cu, ppm	11.3	12.2	11.5	12.0	10.5	11.5	11.8	13.2	11.3	11.2	NS	NS	14.9
Zn, ppm	42.5	59.2	46.2	41.3	51.7	48.0	55.8	63.8	55.7	51.8	NS	NS	24.9
Fe, ppm	146.7	145.0	155.0	156.7	151.7	160.0	161.7	153.3	153.3	151.7	NS	NS	9.6
Mn, ppm	298.3	416.7	370.0	370.0	511.7	518.3	498.3	638.3	676.7	760.0	115.1	NS	29.4
Soil analysis													
Mn,[1] ppm	104.0	117.0	118.3	126.3	121.3	145.3	132.7	150.3	148.3	159.3	10.8	NS	10.5
Mn,[2] ppm	102.0	99.1	100.7	102.1	102.7	103.7	103.7	103.2	101.3	104.3	2.3	NS	2.9
Mn,[3] ppm	185.3	196.3	205.7	209.7	203.0	209.0	201.0	213.3	209.7	219.0	6.1	9.7	3.9
Mn,[4] ppm	126.7	118.7	114.7	126.0	114.3	140.3	125.7	146.0	136.3	159.0	17.0	NS	16.8
Mn,[5] ppm	64.0	77.7	76.3	75.0	72.3	91.0	88.3	99.0	92.0	102.3	9.0	NS	13.8
pH	5.4	5.3	5.2	5.3	5.4	5.2	5.2	5.2	5.1	5.2	—	—	—
O.M., %	0.90	0.90	0.85	0.95	0.83	0.92	0.91	0.94	0.88	0.99	NS	NS	11.7
P, ppm	93.0	99.7	90.3	103.3	95.0	82.7	78.7	68.3	77.7	72.0	NS	NS	14.9
K, ppm	87.7	96.0	93.3	102.7	83.7	87.3	85.3	95.7	79.7	98.3	NS	NS	22.4
Ca, ppm	540.0	490.0	500.0	570.0	600.0	470.0	490.0	490.0	447.0	473.0	NS	NS	11.4
Mg, ppm	141.0	119.0	127.0	142.0	155.0	125.0	139.0	145.0	124.0	140.0	NS	NS	19.6
Cu,[1] ppm	1.40	1.59	1.50	1.57	1.90	1.69	2.12	1.79	1.89	1.51	NS	NS	17.8
Zn,[1] ppm	0.85	1.03	0.73	0.91	0.86	1.00	0.95	1.33	0.88	0.91	NS	NS	30.7
Fe,[1] ppm	34.7	39.1	29.1	34.7	36.3	41.7	43.3	41.5	44.9	41.7	NS	NS	16.0

[1] DTPA-TEA. [2] 0.05 N HCl in 0.025 N H_2SO_4. [3] 0.1 N HCl. [4] 0.1 N H_3PO_4. [5] 1.5 M $NH_4H_2PO_4$.

Table 11. —Influence of applications of S and different rates of Mn on plant and soil chemical analyses and yield of Bragg soybeans grown on Grenada silt loam, Macon Ridge Experiment Station, Winnsboro, La., 1978

	S treatments												
	Na S					S							
	Mn treatments, lbs./acre					Mn treatments, lbs./acre					S	Mn	
Item	0	8.9	17.8	26.8	35.7	0	8.9	17.8	26.8	35.7	LSD$_{.05}$	LSD$_{.05}$	C.V.%
Yield, bu/acre	8.8	7.9	8.8	6.1	8.8	12.2	12.8	9.5	12.5	6.8	NS	NS	39.1
Plant analysis													
P, %	0.21	0.22	0.21	0.22	0.21	0.21	0.22	0.23	0.21	0.22	NS	NS	10.1
K, %	1.43	1.55	1.40	1.55	1.52	1.50	1.53	1.58	1.55	1.45	NS	NS	8.9
Ca, %	1.65	1.63	1.65	1.68	1.58	1.62	1.72	1.63	1.75	1.70	NS	NS	5.0
Mg, %	0.39	0.36	0.41	0.39	0.39	0.38	0.39	0.36	0.39	0.40	NS	NS	8.7
Cu, ppm	13.0	14.7	12.8	12.7	12.3	13.2	13.8	12.8	13.3	13.8	NS	NS	11.2
Zn, ppm	36.2	40.8	34.2	38.2	37.2	38.8	38.3	36.7	37.7	40.5	NS	NS	9.5
Fe, ppm	120.0	131.7	123.3	121.7	121.7	133.3	115.0	116.7	118.3	125.0	NS	NS	8.2
Mn, ppm	223.3	475.0	253.3	315.0	460.0	516.7	423.3	490.0	436.7	600.0	118.8	NS	36.6
Soil analysis													
Mn,[1] ppm	115.0	128.0	102.0	130.3	131.7	135.3	127.0	123.0	122.3	133.0	NS	NS	24.1
Mn,[2] ppm	103.9	105.3	101.6	102.5	104.4	103.3	101.9	104.1	103.5	104.8	NS	NS	4.5
Mn,[3] ppm	206.7	212.0	194.7	210.7	213.3	212.7	215.7	214.7	217.0	212.3	NS	NS	9.1
Mn,[4] ppm	117.3	137.7	106.0	131.7	132.7	144.0	139.3	138.3	139.0	134.0	NS	NS	21.7
Mn,[5] ppm	59.3	85.0	58.3	73.0	76.7	83.3	76.0	80.0	84.3	73.7	14.4	NS	25.0
pH	5.6	5.4	5.4	5.6	5.3	5.6	5.5	5.4	5.3	5.4	—	—	—
O.M., %	1.02	1.17	0.96	0.93	0.98	1.02	1.02	0.98	1.01	1.01	NS	NS	14.1
P, ppm	101.0	118.3	111.0	114.3	118.0	133.3	128.7	116.0	124.7	113.3	NS	NS	8.3
K, ppm	100.7	132.3	117.0	116.0	112.7	138.3	127.7	111.7	125.7	98.0	NS	NS	30.8
Ca, ppm	593.0	547.0	597.0	583.0	563.0	633.0	577.0	603.0	603.0	623.0	NS	NS	13.0
Mg, ppm	175.0	166.0	175.0	206.0	196.0	139.0	131.0	142.0	142.0	146.0	23	NS	18.6
Cu,[1] ppm	1.50	1.84	1.65	1.36	1.83	1.60	1.27	1.72	1.23	1.45	NS	NS	16.6
Zn,[1] ppm	1.26	1.10	1.01	1.06	0.93	1.07	1.02	1.05	1.09	1.05	NS	NS	29.4
Fe,[1] ppm	29.9	36.0	33.6	34.9	36.5	37.3	37.4	37.3	39.5	35.0	NS	NS	14.0

[1] DTPA-TEA. [2] 0.05 N HCl in 0.025 N H_2SO_4. [3] 0.1 N HCl. [4] 0.1 N H_3PO_4. [5] 1.5 M $NH_4H_2PO_4$.

Table 12.—Influence of applications of S and different rates of Mn on plant and soil chemical analyses and yield of Bragg soybeans grown on Grenada silt loam, Macon Ridge Experiment Station, Winnsboro, La., 1979

	S treatments												
	No S					S							
	Mn treatments, lbs./acre					Mn treatments, lbs./acre					S	Mn	
Item	0	8.9	17.8	26.8	35.7	0	8.9	17.8	26.8	35.7	$LSD_{.05}$	$LSD_{.05}$	C.V. %
Yield, bu/acre	22.5	22.1	22.7	20.4	22.7	22.1	25.9	20.8	23.4	20.5	NS	NS	15.2
Plant analysis													
P, %	0.28	0.22	0.27	0.28	0.29	0.25	0.22	0.27	0.28	0.26	NS	NS	17.1
K, %	1.57	1.13	1.51	1.61	1.62	1.36	1.55	1.53	1.48	1.49	NS	NS	17.9
Ca, %	0.67	0.50	0.61	0.60	0.59	0.53	0.59	0.61	0.62	0.58	NS	NS	23.7
Mg, %	0.37	0.27	0.34	0.34	0.36	0.31	0.33	0.34	0.33	0.33	NS	NS	16.1
Cu, ppm	11.7	10.0	10.3	11.8	11.2	10.3	11.3	12.3	11.2	10.7	NS	NS	19.1
Zn, ppm	34.8	32.0	29.8	34.2	40.5	32.3	32.8	37.0	33.3	30.5	NS	NS	23.2
Fe, ppm	115.3	93.3	95.7	110.0	105.7	107.7	102.3	117.3	135.0	108.3	NS	NS	21.1
Mn, ppm	128.3	138.3	111.7	128.3	145.0	136.7	133.3	165.0	155.0	188.3	NS	NS	35.2
Soil analysis													
Mn,[1] ppm	93.2	114.1	94.2	133.1	118.9	113.4	113.5	121.1	134.7	123.0	NS	NS	21.1
Mn,[2] ppm	143.9	153.6	147.9	172.5	164.8	158.7	151.6	165.6	157.7	167.6	NS	NS	16.2
Mn,[3] ppm	194.0	168.3	142.3	191.3	153.3	169.0	168.3	165.3	185.0	172.7	NS	NS	25.3
Mn,[4] ppm	150.3	161.0	158.7	155.3	163.0	180.7	156.0	167.0	180.7	166.7	NS	NS	20.5
Mn,[5] ppm	94.0	111.3	105.0	108.3	103.7	105.0	103.3	113.7	112.7	114.0	NS	NS	12.0
pH	5.7	5.4	5.5	5.4	5.3	5.4	5.4	5.2	5.3	5.2	—	—	—
O.M., %	1.11	1.12	1.08	1.17	0.96	1.06	1.12	1.04	1.12	0.99	NS	NS	11.1
P, ppm	94.0	104.0	89.3	100.0	93.0	104.3	102.0	95.0	97.7	95.3	NS	NS	7.9
K, ppm	112.7	125.7	108.7	121.0	110.0	122.3	112.7	120.7	109.0	101.0	NS	NS	14.6
Ca, ppm	609.0	556.0	593.0	563.0	484.0	494.0	575.0	505.0	547.0	478.0	NS	NS	10.2
Mg, ppm	167.0	152.0	164.0	121.0	110.0	149.0	152.0	127.0	105.0	101.0	NS	28	17.2
Cu,[1] ppm	0.93	0.90	0.87	0.94	0.85	0.97	0.97	0.95	0.95	0.85	NS	NS	9.6
Zn,[1] ppm	0.66	0.68	0.55	0.72	0.69	0.69	0.64	0.64	0.69	0.47	NS	NS	26.3
Fe,[1] ppm	5.29	5.89	5.47	6.22	5.89	6.48	6.55	6.09	6.06	6.48	0.61	NS	13.1

[1] DTPA-TEA. [2] 0.05 N HCl in 0.025 N H_2SO_4. [3] 0.1 N HCl. [4] 0.1 N H_3PO_4. [5] 1.5 M $NH_4H_2PO_4$.

Table 13. —Influence of applications of S and different rates of Mn on plant and soil chemical analyses and yield of Forrest soybeans grown on Grenada silt loam, Macon Ridge Experiment Station, Winnsboro, La., 1979

	S treatments												
	Na S					S							
	Mn treatments, lbs./acre					Mn treatments, lbs./acre							
Item	0	8.9	17.8	26.8	35.7	0	8.9	17.8	26.8	35.7	S LSD$_{.05}$	Mn LSD$_{.05}$	C.V.%
Yield, bu/acre	20.5	21.7	21.7	21.4	20.5	17.5	17.6	17.9	19.3	17.6	NS	NS	11.1
Plant analysis													
P, %	0.27	0.23	0.26	0.25	0.25	0.25	0.24	0.25	0.25	0.24	NS	NS	8.6
K, %	1.28	1.16	1.25	1.22	1.23	1.25	1.19	1.23	1.11	1.10	NS	NS	9.3
Ca, %	0.53	0.48	0.55	0.55	0.55	0.50	0.49	0.55	0.54	0.56	NS	NS	12.8
Mg, %	0.35	0.31	0.35	0.35	0.34	0.33	0.31	0.33	0.35	0.37	NS	NS	10.7
Cu, ppm	10.2	10.0	11.2	9.7	10.2	10.7	9.8	10.7	10.7	10.3	NS	NS	11.5
Zn, ppm	42.5	41.7	40.3	35.8	39.5	42.3	37.0	45.2	44.0	41.0	NS	NS	10.9
Fe, ppm	105.0	100.7	97.7	98.3	111.0	95.3	104.3	105.3	100.3	102.0	NS	NS	20.1
Mn, ppm	151.7	203.3	175.0	205.0	207.0	225.0	225.0	370.0	340.0	365.0	NS	70.9	22.9
Soil analysis													
Mn,[1] ppm	69.7	96.4	111.1	100.8	96.6	125.5	118.1	124.6	109.8	113.8	NS	NS	20.7
Mn,[2] ppm	127.1	153.2	156.5	166.4	151.7	166.1	154.4	168.1	160.4	172.0	NS	NS	8.0
Mn,[3] ppm	120.7	161.0	176.7	180.7	159.3	181.3	177.0	192.3	171.0	191.5	NS	NS	11.6
Mn,[4] ppm	131.0	152.3	180.3	170.3	164.7	169.7	154.7	172.0	167.7	178.0	NS	NS	11.1
Mn,[5] ppm	94.7	119.3	130.7	121.0	118.0	127.0	115.3	125.7	130.3	128.0	8.7	NS	9.4
pH	5.5	5.3	5.4	5.3	5.3	5.4	5.2	5.1	5.1	5.1	—	—	—
O.M., %	0.88	0.99	1.20	1.03	0.96	1.06	0.95	0.98	1.04	0.96	NS	NS	11.1
P, ppm	73.7	83.7	66.3	79.0	67.3	102.3	77.7	72.7	57.7	74.0	NS	NS	20.3
K, ppm	86.7	113.0	91.3	97.3	76.0	94.0	87.7	101.3	85.0	95.0	NS	NS	21.0
Ca, ppm	506.0	461.0	449.0	431.0	458.0	460.0	431.0	408.0	412.0	355.0	50	NS	14.6
Mg, ppm	139.0	123.0	148.0	136.0	146.0	130.0	128.0	118.0	126.0	123.0	18	NS	17.2
Cu,[1] ppm	0.87	0.97	0.78	0.87	0.84	0.93	0.93	0.89	0.94	0.90	NS	NS	14.5
Zn,[1] ppm	0.61	0.85	0.57	0.85	0.59	0.95	0.76	0.79	0.67	0.67	NS	NS	20.7
Fe,[1] ppm	2.66	3.40	2.67	3.12	2.59	3.97	3.26	3.09	3.13	3.80	NS	NS	21.5

[1] DTPA-TEA. [2] 0.05 N HCl in 0.025 N H_2SO_4. [3] 0.1 N HCl. [4] 0.1 N H_3PO_4. [5] 1.5 M $NH_4H_2PO_4$.

Table 14.—Influence of applications of S and different rates of Mn on plant and soil chemical analyses and yield of Bragg soybeans grown on Falaya silt loam, Perkins Road Agronomy Farm, Baton Rouge, La., 1977

	S treatments												
	No S					S							
	Mn treatments, lbs./acre					Mn treatments, lbs./acre					S	Mn	
Item	0	8.9	17.8	26.8	35.7	0	8.9	17.8	26.8	35.7	$LSD_{.05}$	$LSD_{.05}$	C.V.%
Yield, bu/acre	18.2	15.4	15.6	10.9	14.0	8.9	11.5	9.8	9.3	13.2	3.1	NS	31.8
Plant analysis													
P, %	0.32	0.32	0.32	0.31	0.31	0.34	0.34	0.33	0.34	0.34	NS	NS	6.6
K, %	1.40	1.44	1.47	1.47	1.46	1.64	1.60	1.59	1.58	1.58	0.07	NS	6.2
Ca, %	0.99	0.90	0.93	0.86	0.87	0.87	0.84	0.80	0.84	0.87	0.05	NS	7.6
Mg, %	0.31	0.31	0.30	0.31	0.29	0.30	0.29	0.31	0.32	0.30	NS	NS	5.0
Cu, ppm	9.3	10.0	9.3	8.3	8.7	11.3	11.0	12.3	12.3	12.0	NS	NS	8.9
Zn, ppm	64.0	62.3	63.3	57.3	59.3	76.0	71.3	77.3	80.7	80.7	NS	NS	9.5
Fe, ppm	107.0	103.3	134.3	127.3	131.7	106.7	103.7	90.0	91.0	96.3	NS	NS	19.1
Mn, ppm	285.7	293.0	385.3	382.7	340.0	655.3	627.0	948.0	732.0	691.3	304.0	NS	45.5
Soil analysis													
Mn,[1] ppm	68.7	82.3	80.3	77.0	81.0	132.7	102.3	148.0	135.0	131.0	45.0	NS	18.4
Mn,[2] ppm	43.3	53.3	47.7	52.0	50.0	93.0	66.7	110.0	97.0	93.0	NS	NS	27.6
Mn,[3] ppm	73.7	85.7	81.0	87.0	85.0	128.7	99.3	167.7	147.0	133.0	NS	NS	18.4
Mn,[4] ppm	46.3	58.3	50.0	54.0	55.0	96.7	69.3	116.7	100.0	99.0	NS	NS	28.0
Mn,[5] ppm	60.7	74.7	64.0	68.0	71.0	123.0	87.0	146.0	122.0	122.0	NS	NS	27.3
Mn,[6] ppm	0.50	0.83	0.50	0.77	0.80	13.63	2.10	21.00	7.47	8.57	NS	NS	198.1
pH	5.8	5.5	5.6	5.8	5.7	4.8	5.0	4.6	4.6	4.7	—	—	—
O.M., %	1.04	1.09	1.14	0.99	1.04	1.09	1.06	1.08	1.15	1.10	NS	NS	6.7
P, ppm	82.7	74.7	96.3	74.0	69.0	87.0	90.7	77.3	84.3	79.7	NS	NS	19.3
K, ppm	42.3	41.7	47.3	41.7	44.0	49.3	50.7	52.7	54.7	54.3	NS	NS	9.3
Ca, ppm	982.0	887.0	985.0	885.0	932.0	667.0	683.0	607.0	580.0	623.0	142.0	NS	18.3
Mg, ppm	139.0	139.0	135.0	138.0	131.0	109.0	99.0	109.0	101.0	103.0	23.0	NS	6.1
Cu,[1] ppm	0.90	0.96	1.28	0.95	0.90	1.03	0.99	1.05	1.07	1.03	NS	NS	12.6
Zn,[1] ppm	2.37	2.10	2.41	1.57	2.07	2.41	1.93	2.19	2.22	2.17	NS	NS	19.7
Fe,[1] ppm	56.3	63.0	69.0	54.0	60.0	95.3	96.0	97.3	96.3	95.7	15.0	NS	5.8

[1] DTPA-TEA. [2] 0.05 N HCl in 0.[illegible] N H_2SO_4. [3] 0.1 N HCl. [4] 0.1 N H_3PO_4. [5] 1.5 M NH_4H_2[illegible]. [6] H_2O.

Table 15. —Influence of applications of S and different rates of Mn on plant and soil chemical analyses and yield of Lee 74 soybeans grown on Falaya silt loam, Perkins Road Agronomy Farm, Baton Rouge, La., 1977

	S treatments												
	No S					S							
	Mn treatments, lbs./acre					Mn treatments, lbs./acre					S	Mn	
Item	0	8.9	17.8	26.8	35.7	0	8.9	17.8	26.8	35.7	LSD$_{.05}$	LSD$_{.05}$	C.V.%
Yield, bu/acre	11.8	11.1	10.0	9.5	12.0	9.8	11.0	11.0	12.0	12.2	NS	NS	26.2
Plant analysis													
P, %	0.32	0.32	0.32	0.32	0.32	0.31	0.32	0.31	0.34	0.32	NS	NS	7.7
K, %	1.44	1.44	1.47	1.41	1.41	1.47	1.47	1.46	1.55	1.50	NS	NS	8.2
Ca, %	0.91	0.92	0.84	0.93	0.97	0.86	0.85	0.87	0.82	0.81	NS	NS	6.9
Mg, %	0.31	0.32	0.31	0.31	0.32	0.28	0.28	0.27	0.29	0.30	NS	NS	5.1
Cu, ppm	9.3	9.7	10.7	10.3	10.3	12.0	12.0	11.0	11.7	13.0	NS	NS	6.0
Zn, ppm	59.3	58.0	59.7	59.0	62.7	73.3	71.3	78.3	66.7	76.0	NS	NS	10.7
Fe, ppm	93.0	89.3	97.3	96.7	106.7	96.3	85.3	122.0	107.3	80.3	NS	NS	27.9
Mn, ppm	153.7	166.7	251.0	250.3	295.7	653	601	580.0	353.7	434.3	183.0	NS	87.4
Soil analysis													
Mn,[1] ppm	58.3	60.7	79.0	74.0	72.0	110.7	100.7	106.0	87.0	98.0	10	NS	27.4
Mn,[2] ppm	27.0	28.7	36.0	33.0	32.0	75.0	69.0	56.3	48.0	59.0	20	NS	54.1
Mn,[3] ppm	48.7	54.0	61.0	62.0	58.0	109.3	99.0	90.7	75.0	89.0	20	NS	38.4
Mn,[4] ppm	24.7	30.7	36.7	34.0	31.0	79.3	68.7	56.7	51.0	60.0	22	NS	54.3
Mn,[5] ppm	32.0	35.3	42.0	41.0	37.0	97.0	85.0	65.0	55.0	71.0	29	NS	55.2
Mn,[6] ppm	0.30	0.37	0.87	0.53	0.67	9.87	7.50	1.17	1.67	0.93	NS	NS	263.6
pH	6.1	5.9	5.6	5.7	5.8	4.9	5.0	5.0	5.1	5.0	—	—	—
O.M., %	1.12	1.14	1.14	1.15	1.17	1.17	1.15	1.22	1.17	1.20	NS	NS	6.3
P, ppm	62.3	67.3	65.3	62.3	75.0	72.3	77.0	82.0	85.3	81.0	NS	NS	20.2
K, ppm	56.7	55.3	57.7	57.7	60.0	57.0	53.0	63.3	62.3	67.3	NS	NS	13.7
Ca, ppm	1158.0	1067.0	992.0	1037.0	1170.0	760.0	803.0	777.0	802.0	790.0	81	NS	14.0
Mg, ppm	165.0	154.0	150.0	149.0	168.0	122.0	118.0	111.0	124.0	114.0	8	NS	7.7
Cu,[1] ppm	0.93	0.81	0.96	0.81	0.99	0.90	0.80	1.03	1.04	0.99	NS	NS	12.4
Zn,[1] ppm	1.43	1.57	1.35	1.56	1.96	1.51	1.71	2.01	1.47	1.64	NS	NS	22.8
Fe,[1] ppm	51.0	55.0	61.7	57.0	59.3	86.0	81.7	99.0	89.0	92.3	13.0	NS	10.8

[1] DTPA-TEA. [2] 0.05 N HCl in 0.025 N H_2SO_4. [3] 0.1 N HCl. [4] 0.1 N H_3PO_4. [5] 1.5 M $NH_4H_2PO_4$. [6] H_2O.

In 1978 (Tables 16 and 17), the concentrations of DTPA-extractable Fe and Mn were significantly higher in plots receiving S than in plots not receiving S for the Bragg and Lee 74 cultivars. However, the concentrations of extractable soil Ca and Mg decreased significantly for the plots receiving S only for the Lee 74 cultivar. A similar nonsignificant trend may be seen for extractable soil Ca and Mg for the Bragg cultivar. The leaf tissue of Lee 74 soybeans grown in plots receiving S contained a significantly higher concentration of Mn than soybeans grown in plots receiving no S. For the Bragg cultivar, a similar nonsignificant relationship may be seen. For both cultivars, there was a significant difference among Mn treatments with respect to DTPA-extractable Mn, but the higher rates of Mn did not consistently produce the higher soil test values.

In 1979 (Table 19) for Lee 74 soybeans in plots receiving S, the leaf tissue Mn and the DTPA-extractable soil Mn and Fe were significantly higher than for plots receiving no S. There was a significant difference among Mn treatments with respect to extractable soil P, the check plots averaging 123 μg P/g and the treated plots averaging less than 100 μg P/g. However, leaf tissue analysis showed adequate concentrations of P for all rates of Mn.

For Bragg soybeans in 1979 (Table 18), the concentration of DTPA-extractable soil Fe was significantly higher for plots receiving S than for plots receiving no S. Plots treated with S tended to have lower concentrations of extractable soil Ca and Mg, and tissue Ca and Mg than plots treated with no S. However, the difference between S treatments was statistically significant for soil Mg.

The residual effects of applications of different rates of S and Mn on the yield of soybeans in 1980 at each of the four locations are shown in Table 20, since Mn and S were not applied in 1980. The data indicate no significant differences among treatments with respect to yield at any location. The low yields obtained on the Grenada soil were attributed to dry weather.

Simple correlation coefficients for soybean yield and Mn concentrations in the leaf tissue and various soil extractants are shown in Tables 21-32. Tables 31 and 32 include correlations with extractable soil Ca. Correlation analysis of yield and leaf Mn was significant for the following conditions: 1979, Forrest, Norwood silt loam, r = −0.533, Table 23; 1977, Forrest, Grenada silt loam, r = −0.369, Table 27; 1979, Forrest, Grenada silt loam, r = −0.533, Table 29; and 1977, Bragg, Falaya silt loam, r = −0.708, Table 30.

It should be noted that all significant correlations were negative, which implies excessive Mn in the leaf tissue.

Correlation analysis of yield and extractable soil Ca resulted in significance in 1979 (Table 32) for the Bragg cultivar grown on Falaya silt loam, r = 0.619. The Falaya soil contains a relatively high amount of native Mn and is poorly drained. And, in the lower areas at this location extractable soil Ca concentrations ranged from 500-600 μg/g, while in the higher, better drained areas soil Ca ranged from 650-1,000 μg/g. Mengel and Kirkby (*13*) state that Ca is absorbed through the root tips. Therefore, poor drainage and aeration in the Falaya soil may have contributed to less root development with a depression in Ca uptake and yield for the more poorly drained plots. DTPA-extractable soil Mn was negatively correlated with extractable soil Ca (r = −0.461) and with yield (r = −0.440). Mn antagonism may also have depressed Ca uptake and yield.

In 1978 (Table 31), the leaf tissue Mn of Lee 74 and Bragg soybeans were each negatively correlated with extractable soil Ca, r = −0.657 and r = −0.578, respectively.

At each of the four locations the correlation coefficients of leaf tissue Mn and extractable soil Mn by the six methods did not show one extractant to be clearly superior to another. Significant correlations for the Norwood silt loam and the Severn very fine sandy loam were inconsistent among years and cultivars.

For the Falaya silt loam in 1979 (Table 32) there were no significant correlations of leaf Mn with soil Mn. In 1978 (Table 31), only DTPA-TEA (r = 0.520) for Lee 74 cultivar was significantly correlated with leaf tissue Mn. In 1977 (Table 30), for the Bragg cultivar DTPA-TEA (r = 0.703) was more highly correlated with leaf Mn than the other extractants, and for the Lee 74 cultivar MAP, 1.5 M $NH_4H_2PO_4$, (r = 0.686), and DTPA-TEA (r = 0.573) were the first and second most highly correlated with leaf Mn.

For the Grenada silt loam in 1977 (Table 27), H_2O (r = 0.849) was more highly correlated with tissue Mn for the Bragg cultivar and double acid (r = 0.896) for the Forrest cultivar than the other extractants. But, H_2O was significantly correlated with tissue Mn (r = 0.850) for the Forrest cultivar as well. DTPA-TEA was well correlated with leaf Mn for Forrest (r = 0.884) but not as well for Bragg soybeans (r = 0.461). In 1978 (Table 28), DTPA-TEA (r = 0.797) was more highly correlated with tissue Mn in Forrest soybeans than the other extractants, and MAP (r = 0.781) was more highly correlated for the Bragg cultivar. For the Bragg cultivar the DTPA-TEA correlation with leaf Mn (r = 0.606) followed MAP. In 1979 (Table 29), all of the extractants were either poorly correlated or not significantly correlated with leaf Mn for the two cultivars.

In all years there were numerous significant correlations between the different extractants for soil Mn. However, these results and others, previously reported, do not support the use of one extractant rather than another for the prediction of Mn availability and uptake by the plant. In general, with respect to extractable soil Mn, the data show that for a given extraction method there was substantial variation among years. Although statistical significance among treatments may have been established, the higher soil

Table 16. —Influence of applications of S and different rates of Mn on plant and soil chemical analyses and yield of Bragg soybeans grown on Falaya silt loam, Perkins Road Agronomy Farm, Baton Rouge, La., 1978

	S treatments												
	Na S					S							
	Mn treatments, lbs./acre					Mn treatments, lbs./acre					S	Mn	
Item	0	8.9	17.8	26.8	35.7	0	8.9	17.8	26.8	35.7	LSD$_{.05}$	LSD$_{.05}$	C.V.%
Yield, bu/acre	33.6	34.1	39.4	34.5	39.8	37.0	34.8	28.2	31.7	33.0	NS	NS	42.9
Plant analysis													
P, %	0.26	0.25	0.27	0.25	0.26	0.27	0.26	0.23	0.25	0.25	NS	NS	8.3
K, %	1.03	0.98	1.15	1.02	1.00	1.08	1.15	0.90	1.08	1.10	NS	NS	9.1
Ca, %	1.37	1.28	1.15	1.18	1.23	1.13	1.22	1.17	1.22	1.15	NS	NS	14.4
Mg, %	0.45	0.47	0.45	0.48	0.40	0.43	0.42	0.45	0.45	0.43	NS	NS	12.5
Cu, ppm	12.8	15.8	14.3	13.8	13.8	14.2	13.8	13.7	13.3	15.3	NS	NS	11.3
Zn, ppm	65.3	66.2	59.2	58.8	63.0	65.3	63.7	67.0	74.8	66.0	NS	NS	19.0
Fe, ppm	135.0	135.3	125.3	140.0	126.7	126.0	126.0	129.3	127.0	121.3	NS	NS	11.6
Mn, ppm	211.7	207.7	200.0	208.3	231.3	253.3	287.7	344.0	366.0	261.0	NS	NS	39.8
Soil analysis													
Mn,[1] ppm	104.0	104.7	102.7	102.7	112.3	105.3	107.3	111.7	133.3	124.0	5.9	9.4	6.9
Mn,[2] ppm	94.9	93.7	95.2	93.4	96.9	93.2	93.6	96.4	97.5	98.8	1.5	2.3	2.0
Mn,[3] ppm	184.3	186.7	188.7	184.7	191.7	182.7	184.3	189.3	204.0	203.0	NS	6.4	2.7
Mn,[4] ppm	68.3	75.3	74.7	72.3	76.3	75.7	75.3	76.0	86.7	85.3	NS	NS	9.2
Mn,[5] ppm	64.0	73.3	68.0	63.0	71.0	69.7	76.0	71.0	53.7	67.3	NS	NS	17.3
pH	5.5	5.2	5.4	5.5	5.5	5.0	5.1	5.1	4.9	5.0	—	—	—
O.M., %	1.04	1.14	0.98	0.88	0.91	1.06	1.15	1.07	0.93	1.00	NS	0.07	5.8
P, ppm	97.0	80.0	115.7	79.7	85.7	87.0	110.0	154.3	115.7	116.7	NS	NS	30.8
K, ppm	46.7	45.0	56.0	43.0	43.0	44.7	53.7	57.0	53.3	57.3	NS	NS	16.8
Ca, ppm	867.0	793.0	880.0	773.0	807.0	743.0	727.0	783.0	697.0	697.0	NS	NS	10.5
Mg, ppm	134.0	126.0	133.0	126.0	129.0	119.0	110.0	124.0	104.0	107.0	NS	NS	9.2
Cu,[1] ppm	3.2	3.6	3.3	3.2	3.3	3.6	4.3	3.4	2.8	3.1	NS	NS	23.3
Zn,[1] ppm	2.6	2.4	2.7	2.8	2.6	2.6	2.5	2.8	2.3	2.6	NS	NS	16.1
Fe,[1] ppm	8.4	8.9	8.7	8.3	8.7	10.3	10.9	10.5	10.5	10.9	0.7	NS	9.0

[1] DTPA-TEA. [2] 0.05 N HCl in 0.025 N H_2SO_4. [3] 0.1 N HCl. [4] 0.1 N H_3PO_4. [5] 1.5 M $NH_4H_2PO_4$.

Table 17.—Influence of applications of S and different rates of Mn on plant and soil chemical analyses and yield of Lee 74 soybeans grown on Falaya silt loam, Perkins Road Agronomy Farm, Baton Rouge, La., 1978

Item	S treatments												
	No S					S							
	Mn treatments, lbs./acre					Mn treatments, lbs./acre					S LSD$_{.05}$	Mn LSD$_{.05}$	C.V.%
	0	8.9	17.8	26.8	35.7	0	8.9	17.8	26.8	35.7			
Yield, bu/acre	39.4	41.6	42.8	42.1	40.0	41.0	40.7	38.5	39.8	42.4	NS	NS	10.3
Plant analysis													
P, %	0.24	0.26	0.29	0.26	0.24	0.26	0.25	0.23	0.24	0.25	NS	NS	8.9
K, %	0.97	1.12	1.00	1.10	1.12	1.15	1.10	1.10	1.22	1.03	NS	NS	10.9
Ca, %	1.33	1.27	1.28	1.07	1.25	1.25	1.23	1.25	1.17	1.20	NS	NS	11.6
Mg, %	0.40	0.38	0.38	0.40	0.38	0.37	0.38	0.37	0.40	0.33	NS	NS	9.5
Cu, ppm	14.7	14.0	15.5	13.6	13.7	14.8	15.0	15.3	14.8	15.0	NS	NS	6.2
Zn, ppm	61.3	60.3	62.5	59.2	61.3	70.3	69.0	77.2	63.8	66.7	NS	NS	8.4
Fe, ppm	128.0	108.0	112.3	106.3	104.7	126.0	114.7	115.7	116.7	109.3	NS	NS	12.7
Mn, ppm	140.0	143.3	168.0	176.3	164.0	259.0	228.3	217.3	184.7	223.0	46.1	NS	31.3
Soil analysis													
Mn,[1] ppm	86.3	85.0	101.7	108.0	107.0	112.0	108.0	112.7	113.3	127.0	6.9	10.9	8.4
Mn,[2] ppm	94.3	97.5	96.8	96.3	97.2	96.3	98.3	97.6	97.3	97.1	1.7	NS	2.3
Mn,[3] ppm	182.3	184.0	192.0	193.7	197.7	186.3	193.0	190.7	193.7	199.0	NS	8.2	3.5
Mn,[4] ppm	68.7	71.7	70.0	68.0	71.3	67.7	71.7	71.7	73.3	78.0	NS	NS	9.7
Mn,[5] ppm	64.7	66.7	56.7	62.7	54.0	63.3	60.0	59.0	62.0	70.3	NS	NS	25.1
pH	5.7	5.7	5.4	5.5	5.5	5.0	5.2	5.1	5.3	4.9	—	—	—
O.M., %	1.07	0.91	1.01	0.99	1.06	1.07	1.03	1.09	1.01	0.98	NS	NS	6.1
P, ppm	93.3	192.7	98.0	129.0	138.3	108.0	128.0	140.3	124.7	148.3	NS	NS	26.6
K, ppm	62.3	86.0	60.3	70.7	62.7	67.0	73.0	68.0	71.0	82.7	NS	NS	19.9
Ca, ppm	980.0	990.0	810.0	937.0	937.0	803.0	817.0	803.0	790.0	797.0	65	NS	9.7
Mg, ppm	159.0	145.0	138.0	144.0	147.0	124.0	123.0	117.0	120.0	117.0	9	NS	8.6
Cu,[1] ppm	2.8	3.5	3.2	3.8	3.9	2.6	4.0	3.6	3.1	3.6	NS	0.2	15.9
Zn,[1] ppm	2.1	2.3	1.9	2.5	2.6	2.0	2.4	2.6	2.1	2.4	NS	NS	20.7
Fe,[1] ppm	6.6	7.3	8.0	8.2	8.3	9.9	10.0	10.3	15.2	10.6	0.6	NS	9.1

[1] DTPA-TEA. [2] 0.05 N HCl in 0.025 N H_2SO_4. [3] 0.1 N HCl. [4] 0.1 N H_3PO_4. [5] 1.5 M $NH_4H_2PO_4$.

Table 18. —Influence of applications of S and different rates of Mn on plant and soil chemical analyses and yield of Bragg soybeans grown on Falaya silt loam, Perkins Road Agronomy Farm, Baton Rouge, La., 1979

	S treatments												
	No S					S							
	Mn treatments, lbs./acre					Mn treatments, lbs./acre					S	Mn	
Item	0	8.9	17.8	26.8	35.7	0	8.9	17.8	26.8	35.7	LSD$_{.05}$	LSD$_{.05}$	C.V.%
Yield, bu/acre	8.6	9.3	10.3	10.1	9.8	12.7	10.8	8.5	10.5	10.7	NS	NS	43.5
Plant analysis													
P, %	0.25	0.24	0.28	0.26	0.27	0.28	0.28	0.25	0.23	0.26	NS	NS	13.8
K, %	1.09	1.00	1.16	1.10	1.21	1.20	1.18	1.23	1.16	1.08	NS	NS	8.0
Ca, %	1.33	1.31	1.36	1.26	1.33	1.24	1.20	1.21	1.17	1.10	NS	NS	11.2
Mg, %	0.28	0.29	0.29	0.30	0.30	0.27	0.26	0.28	0.26	0.24	NS	NS	16.9
Cu, ppm	6.7	6.5	6.8	6.7	6.2	7.5	7.0	8.2	7.5	7.2	NS	NS	11.3
Zn, ppm	64.3	69.0	75.0	66.0	72.3	71.0	71.7	77.2	69.2	72.8	NS	NS	12.8
Fe, ppm	151.7	134.0	131.3	126.0	127.7	125.3	137.7	131.3	130.7	118.3	NS	NS	12.2
Mn, ppm	240.0	286.7	313.3	230.0	273.3	285.0	526.7	460.0	475.0	520.0	NS	NS	55.2
Soil analysis													
Mn,[1] ppm	91.0	114.8	100.8	103.5	95.1	99.9	107.1	145.7	124.2	121.3	NS	NS	28.4
Mn,[2] ppm	126.9	134.0	134.0	137.1	135.5	131.9	139.2	170.4	150.3	146.8	NS	NS	15.7
Mn,[3] ppm	143.3	154.7	142.7	144.0	155.3	143.7	157.3	190.7	164.3	160.7	NS	NS	15.1
Mn,[4] ppm	108.0	120.3	112.7	125.0	119.7	126.7	126.3	196.0	152.3	133.0	NS	NS	19.1
Mn,[5] ppm	106.3	111.3	103.7	110.7	107.3	105.3	126.7	137.7	118.3	114.3	NS	NS	14.6
pH	5.7	5.3	5.4	5.3	5.1	5.0	5.1	4.8	4.8	4.8	—	—	—
O.M., %	1.18	1.45	1.30	0.99	1.01	1.14	1.09	1.12	1.03	1.19	NS	NS	17.8
P, ppm	88.0	110.7	104.0	91.7	123.7	104.7	109.3	92.7	96.0	101.0	NS	NS	16.8
K, ppm	58.7	58.7	60.0	63.3	62.7	64.3	65.3	60.7	65.7	73.3	NS	NS	13.3
Ca, ppm	938.0	798.0	844.0	751.0	814.0	734.0	763.0	717.0	654.0	683.0	NS	NS	13.3
Mg, ppm	155.0	129.0	135.0	130.0	124.0	113.0	123.0	124.0	108.0	108.0	8	NS	7.8
Cu,[1] ppm	1.5	1.6	1.5	1.5	1.4	1.7	1.6	1.6	1.7	1.7	NS	NS	11.7
Zn,[1] ppm	2.9	2.3	3.0	2.2	2.5	2.5	2.4	2.9	2.5	2.5	NS	NS	20.0
Fe,[1] ppm	10.3	11.3	11.6	11.6	11.2	15.0	14.5	15.0	15.7	16.0	1.1	NS	20.0

[1] DTPA-TEA. [2] 0.05 *N* HCl in 0.025 *N* H_2SO_4. [3] 0.1 *N* HCl. [4] 0.1 *N* H_3PO_4. [5] 1.5 *M* $NH_4H_2PO_4$.

Table 19.—Influence of applications of S and different rates of Mn on plant and soil chemical analyses and yield of Lee 74 soybeans grown on Falaya silt loam, Perkins Road Agronomy Farm, Baton Rouge, La., 1979

Item	S treatments												
	No S					S					S	Mn	
	Mn treatments, lbs./acre					Mn treatments, lbs./acre					LSD$_{.05}$	LSD$_{.05}$	C.V.%
	0	8.9	17.8	26.8	35.7	0	8.9	17.8	26.8	35.7			
Yield, bu/acre	15.9	17.1	17.5	16.3	19.1	15.7	16.8	16.4	14.7	12.0	NS	NS	21.7
Plant analysis													
P, %	0.25	0.25	0.23	0.23	0.24	0.24	0.25	0.25	0.23	0.23	NS	NS	6.8
K, %	1.30	1.42	1.33	1.30	1.44	1.43	1.45	1.41	1.41	1.42	NS	NS	6.9
Ca, %	1.17	1.13	1.14	1.14	1.21	1.09	1.16	1.10	1.07	1.12	NS	NS	6.9
Mg, %	0.22	0.21	0.21	0.20	0.22	0.22	0.21	0.19	0.21	0.21	NS	NS	7.8
Cu, ppm	8.3	9.0	7.5	8.2	8.0	8.5	8.3	9.3	8.5	7.8	NS	NS	16.4
Zn, ppm	56.5	55.0	56.0	57.5	53.2	63.7	57.8	61.7	56.8	61.0	NS	NS	8.3
Fe, ppm	140.3	128.0	93.3	98.0	97.0	137.3	98.3	112.0	128.7	105.0	NS	NS	41.9
Mn, ppm	261.7	453.3	245.0	273.3	218.3	456.7	340.0	548.3	363.3	400.0	154.1	NS	55.9
Soil analysis													
Mn,[1] ppm	75.3	77.9	82.5	90.9	95.9	88.7	88.4	89.7	100.1	92.0	6.8	NS	10.0
Mn,[2] ppm	118.8	122.0	126.0	139.6	138.0	127.9	122.9	128.4	136.0	128.8	NS	7.1	4.5
Mn,[3] ppm	126.3	142.3	146.0	160.7	159.3	144.0	144.3	151.0	158.0	156.3	7.2	11.4	6.3
Mn,[4] ppm	104.0	102.7	110.0	118.3	121.7	110.0	108.7	112.3	121.3	113.7	NS	6.6	4.8
Mn,[5] ppm	99.0	100.3	109.7	110.3	111.7	104.0	97.0	104.7	114.0	107.3	NS	6.7	5.2
pH	5.0	5.1	5.1	5.0	5.3	5.4	5.3	5.6	5.6	4.9	—	—	—
O.M., %	1.12	1.07	1.11	1.08	1.19	1.11	1.10	1.03	0.99	1.09	NS	NS	5.5
P, ppm	123.7	98.3	87.0	86.0	83.7	123.3	81.7	85.3	78.0	103.7	NS	11.4	9.8
K, ppm	59.0	57.7	58.3	61.0	59.0	65.0	53.7	53.7	56.7	65.7	NS	NS	8.5
Ca, ppm	812.0	824.0	800.0	750.0	842.0	847.0	870.0	872.0	921.0	768.0	NS	NS	9.4
Mg, ppm	126.0	123.0	129.0	123.0	134.0	131.0	134.0	142.0	154.0	123.0	NS	NS	8.5
Cu,[1] ppm	1.3	1.4	1.3	1.4	1.5	1.5	1.5	1.5	1.5	1.5	0.1	NS	6.9
Zn,[1] ppm	1.8	2.0	1.6	2.0	2.1	1.8	2.0	2.3	2.0	1.9	NS	NS	20.4
Fe,[1] ppm	8.8	9.6	9.5	10.7	10.2	13.2	12.5	13.3	13.3	13.0	1.0	NS	11.3

[1] DTPA-TEA. [2] 0.05 N HCl in 0.025 N H_2SO_4. [3] 0.1 N HCl. [4] 0.1 N H_3PO_4. [5] 1.5 M $NH_4H_2PO_4$.

Table 20.—Influence of applications of S and different rates of Mn on yields of soybeans grown on selected soils, 1980

		S treatments										
		No S					S					
		Mn treatments, lbs./acre					Mn treatments, lbs./acre					
Soil type[1]	Cultivar	0	8.9	17.8	26.8	35.7	0	8.9	17.8	26.8	35.7	C.V.%
		Yield, bu/acre (13% moisture)[2]										
Norwood sil	Forrest	33.6	34.1	34.2	34.1	32.9	—	—	—	—	—	19.1
	Bragg	37.3	39.4	41.8	37.9	37.6	—	—	—	—	—	10.6
Severn vfsl	Centennial	22.8	24.3	23.4	21.6	21.8	—	—	—	—	—	10.5
	Bragg	32.4	30.0	30.3	30.7	30.6	—	—	—	—	—	4.2
Granada sil	Forrest	5.4	5.5	5.9	5.2	6.9	4.4	6.4	4.7	7.7	6.4	45.1
	Bragg	6.3	8.5	5.6	3.7	8.0	6.3	6.7	7.2	6.5	7.5	16.2
Falaya sil	Lee 74	28.3	31.6	30.5	30.1	27.5	31.5	32.0	28.5	33.0	31.0	51.3
	Bragg	23.2	25.7	27.9	23.5	23.8	24.6	27.0	23.1	23.9	33.1	25.1

[1] sil = silt loam; vfsl = very fine sandy loam.

[2] None of the differences in yields were statistically significant within soil type and cultivar.

Table 21. —Simple correlation coefficients (r) for soybean yield and leaf and soil Mn concentrations, Dean Lee Agricultural Center, 1977

Cultivar	Variable	Leaf Mn	Soil Mn extractant: DTPA-TEA	H_2O	Double acid[1]	MAP[2]	H_3PO_4	HCL
		Simple correlation coefficients (r)						
Bragg	Yield	−0.050	−0.642**	−0.528*	−0.176	−0.177	−0.264	−0.266
	Leaf Mn		0.315	−0.001	0.155	0.564**	0.220	0.108
	Soil Mn extractant							
	DTPA-TEA			0.420	0.243	0.363	0.347	0.282
	H_2O				0.374	0.169	0.398	0.076
	Double acid					0.502*	0.971**	−0.267
	MAP						0.593**	−0.004
	H_3PO_4							−0.245
Forrest	Yield	−0.247	0.573**	−0.312	0.124	0.006	0.219	0.242
	Leaf Mn		−0.348	0.265	−0.227	−0.017	−0.242	0.048
	Soil Mn extractant							
	DTPA-TEA			−0.264	0.225	0.368	0.228	0.283
	H_2O				−0.037	0.005	−0.064	−0.198
	Double acid					0.165	0.944**	−0.259
	MAP						0.209	0.537*
	H_3PO_4							−0.129

[1] 0.05 N HCL + 0.025 N H_2SO_4.

[2] 1.5 M $NH_4H_2PO_4$.

*Significant at the 5% level of probability.

**Significant at the 1% level of probability.

Table 22.—Simple correlation coefficients (r) for soybean yield and leaf and soil Mn concentrations, ,Dean Lee Agricultural Center, 1978

			Soil Mn extractant				
Cultivar	Variable	Leaf Mn	DTPA-TEA	Double acid[1]	MAP[2]	H_3PO_4	HCL
		Simple correlation coefficients (r)					
Bragg	Yield	−0.239	0.022	−0.027	0.049	0.227	−0.218
	Leaf Mn		0.530*	0.107	0.264	−0.114	0.233
	Soil Mn extractant						
	DTPA-TEA			0.212	0.407	−0.311	0.600**
	Double acid				−0.013	0.032	0.089
	MAP					−0.326	0.298
	H_3PO_4						−0.253
Farrest	Yield	−0.160	−0.118	0.084	−0.454*	−0.022	−0.035
	Leaf Mn		0.267	−0.066	0.029	−0.099	−0.096
	Soil Mn extractant						
	DTPA-TEA			0.374	0.105	−0.064	0.111
	Double acid				0.184	−0.018	−0.048
	MAP					0.004	−0.127
	H_3PO_4						−0.089

[1] 0.05 N HCL + 0.025 N H_2SO_4.

[2] 1.5 M $NH_4H_2PO_4$.

*Significant at the 5% level of probability.

**Significant at the 1% level of probability.

Table 23.—Simple correlation coefficients (r) for soybean yield and leaf and soil Mn concentrations, Dean Lee Agricultural Center, 1979

Cultivar	Variable	Leaf Mn	Soil Mn extractant				
			DTPA-TEA	Dauble acid[1]	MAP[2]	H_3PO_4	HCL
		----------	Simple correlation caefficients (r)	----------			
Bragg	Yield	0.047	0.313	0.265	0.169	0.010	0.187
	Leaf Mn		0.134	−0.256	−0.227	0.185	0.170
	Sail Mn extractant						
	DTPA-TEA			0.229	0.572**	0.767**	0.583**
	Double acid				0.165	0.327	0.255
	MAP					0.501*	0.741**
	H_3PO_4						0.691**
Farrest	Yield	−0.533*	0.133	0.564**	−0.327	−0.250	0.446*
	Leaf Mn		−0.435	−0.485*	0.097	0.152	−0.315
	Soil Mn extractant						
	DTPA-TEA			0.417	−0.045	0.328	0.109
	Dauble acid				−0.404	−0.243	0.137
	MAP					−0.614**	0.116
	H_3PO_4						0.317

[1] 0.05 N HCL + 0.025 N H_2SO_4.

[2] 1.5 M $NH_4H_2PO_4$.

*Significant at the 5% level of probability.

**Significant at the 1% level of prabability.

Table 24.—Simple correlation coefficients (r) for soybean yield and leaf and soil Mn concentrations, Red River Valley Experiment Station, 1977

			Soil Mn extractant					
Cultivar	Variable	Leaf Mn	DTPA-TEA	H_2O	Double acid[1]	MAP[2]	H_3PO_4	HCL
		Simple correlation coefficients (r)						
Bragg	Yield	0.322	0.245	0.339	0.021	0.172	0.376	0.003
	Leaf Mn		0.084	0.156	−0.150	−0.124	0.102	−0.071
	Soil Mn extractant							
	DTPA-TEA			0.546*	0.042	0.631**	0.436	0.027
	H_2O				−0.213	0.559*	0.255	−0.202
	Double acid					−0.057	0.722**	0.754**
	MAP						0.248	−0.156
	H_3PO_4							0.660**
Centennial	Yield	0.110	0.147	0.214	0.180	0.043	0.554*	0.238
	Leaf Mn		−0.525*	0.491*	−0.288	−0.378	0.124	−0.059
	Soil Mn extractant							
	DTPA-TEA			−0.178	0.488*	0.338	0.228	0.225
	H_2O				−0.196	−0.215	0.030	−0.366
	Double acid					0.345	0.731**	0.564**
	MAP						0.407	0.570**
	H_3PO_4							0.686**

[1] 0.05 *N* HCL + 0.025 *N* H_2SO_4.

[2] 1.5 M $NH_4H_2PO_4$.

*Significant at the 5% level of probability.

**Significant at the 1% level of probability.

Table 25. —Simple correlation coefficients (r) for soybean yield and leaf and soil Mn concentrations, Red River Valley Experiment Station, 1978

Cultivar	Variable	Leaf Mn	Soil Mn extractant				
			DTPA-TEA	Double acid[1]	MAP[2]	H_3PO_4	HCL
		Simple correlation coefficients (r)					
Bragg	Yield	−0.045	0.255	0.080	0.264	−0.024	−0.323
	Leaf Mn		−0.266	−0.314	−0.234	−0.288	−0.463
	Soil Mn extractant						
	DTPA-TEA			0.139	0.559*	0.420	0.005
	Double acid				0.315	0.101	0.000
	MAP					0.292	−0.177
	H_3PO_4						0.702**
Centennial	Yield	0.189	−0.031	0.305	0.412	0.492*	0.179
	Leaf Mn		−0.042	0.592**	−0.153	0.457*	0.701**
	Soil Mn extractant						
	DTPA-TEA			0.360	0.143	0.254	0.314
	Double acid				0.118	0.795**	0.853**
	MAP					0.227	−0.138
	H_3PO_4						0.649**

[1] 0.05 N HCL + 0.025 N H_2SO_4.

[2] 1.5 M $NH_4H_2PO_4$.

*Significant at the 5% level of probability.

**Significant at 1% level of probability.

Table 26. —Simple correlation coefficients (r) for soybean yield and leaf and soil Mn concentrations, Red River Valley Experiment Station, 1979

Cultivar	Variable	Leaf Mn	Soil Mn extractant				
			DTPA-TEA	Double acid[1]	MAP[2]	H_3PO_4	HCL
		Simple correlation coefficients (r)					
Bragg	Yield	−0.056	0.085	0.071	−0.115	0.052	0.014
	Leaf Mn		0.283	0.124	0.650**	0.188	0.197
	Soil Mn extractant						
	DTPA-TEA			0.390	0.458*	0.442	0.490*
	Double acid				0.249	0.872**	0.751**
	MAP					0.465*	0.434
	H_3PO_4						0.737**
Centennial	Yield	0.097	0.499*	0.108	−0.074	0.115	0.129
	Leaf Mn		0.100	0.211	0.264	0.435	0.539*
	Soil Mn extractant						
	DTPA-TEA			0.153	−0.002	0.028	0.193
	Double acid				0.585**	0.793**	0.884**
	MAP					0.528*	0.680**
	H_3PO_4						0.887**

[1] 0.05 N HCL + 0.025 N H_2SO_4.

[2] 1.5 M $NH_4H_2PO_4$.

*Significant at the 5% level of probability.

**Significant at the 1% level of probability.

Table 27. —Simple correlation coefficients (r) for soybean yield and leaf and soil Mn concentrations, Macon Ridge Experiment Station, 1977

Cultivar	Variable	Leaf Mn	Soil Mn extractant					
			DTPA-TEA	H_2O	Double acid[1]	MAP[2]	H_3PO_4	HCL
		Simple correlation coefficients (r)						
Bragg	Yield	−0.334	0.023	−0.179	−0.035	−0.071	0.024	−0.058
	Leaf Mn		0.461*	0.849**	0.591**	−0.485**	0.557**	0.421*
	Soil Mn extractant							
	DTPA-TEA			0.571**	0.966**	−0.503**	0.963**	0.969**
	H_2O				0.678**	−0.468**	0.648**	0.546**
	Double acid					−0.553**	0.993**	0.949**
	MAP						−0.555**	0.472**
	H_3PO_4							0.942**
Farrest	Yield	−0.369*	−0.487**	−0.297	−0.532**	0.400*	−0.499**	−0.502**
	Leaf Mn		0.884**	0.850**	0.896**	−0.259	0.861**	0.872**
	Soil Mn extractant							
	DTPA-TEA			0.833**	0.973**	−0.251	0.966**	0.968**
	H_2O				0.863**	−0.282	0.856**	0.869**
	Double acid					−0.320	0.989**	0.985**
	MAP						−0.307	−0.336
	H_3PO_4							0.981**

[1] 0.05 N HCL + 0.025 N H_2SO_4.

[2] 1.5 M $NH_4H_2PO_4$.

*Significant at the 5% level of probability.

**Significant at the 1% level of probability.

Table 28. —Simple correlation coefficients (r) for soybean yield and leaf and soil Mn concentrations, Macon Ridge Experiment Station, 1978

Cultivar	Variable	Leaf Mn	Soil Mn extractant				
			DTPA-TEA	Double acid[1]	MAP[2]	H_3PO_4	HCL
		Simple correlation coefficients (r)					
Bragg	Yield	−0.309	−0.100	−0.163	−0.171	−0.007	0.166
	Leaf Mn		0.606**	0.030	0.781**	0.579**	0.203
	Soil Mn extractant						
	DTPA-TEA			0.027	0.779**	0.864**	0.699**
	Double acid				0.058	0.062	0.082
	MAP					0.874**	0.539**
	H_3PO_4						0.855**
Farrest	Yield	−0.192	−0.380*	−0.118	−0.437*	−0.215	−0.156
	Leaf Mn		0.797**	0.088	0.720**	0.631**	0.578**
	Soil Mn extractant						
	DTPA-TEA			0.250	0.933**	0.769**	0.761**
	Double acid				0.114	0.169	0.269
	MAP					0.709**	0.640**
	H_3PO_4						0.613**

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[1] 0.05 N HCL + 0.025 N H_2SO_4.

[2] 1.5 M $NH_4H_2PO_4$.

*Significant at the 5% level of probability.

**Significant at the 1% level of probability.

Table 29. —Simple correlation coefficients (r) for soybean yield and leaf and soil Mn concentrations, Macon Ridge Experiment Station, 1979

Cultivar	Variable	Leaf Mn	Soil Mn extractant				
			DTPA-TEA	Double acid[1]	MAP[2]	H_3PO_4	HCL
		Simple correlation coefficients (r)					
Bragg	Yield	−0.144	0.317	0.376*	0.138	0.124	0.380*
	Leaf Mn		0.393*	0.198	0.409*	0.243	0.106
	Soil Mn extractant						
	DTPA-TEA			0.699**	0.741**	0.540**	0.571**
	Double acid				0.684**	0.474**	0.632**
	MAP					0.673**	0.539*
	H_3PO_4						0.378*
Forrest	Yield	−0.533**	−0.402*	−0.529**	−0.304	−0.400*	−0.375*
	Leaf Mn		0.453	0.544**	0.400*	0.413*	0.402*
	Soil Mn extractant						
	DTPA-TEA			0.803**	0.580**	0.672**	0.815**
	Double acid				0.620**	0.826**	0.851**
	MAP					0.725**	0.754**
	H_3PO_4						0.768**

[1] 0.05 N HCL + 0.025 N H_2SO_4.

[2] 1.5 M $NH_4H_2PO_4$.

* Significant at the 5% level of probability.

** Significant at 1% level of probability.

Table 30. —Simple correlation coefficients (r) for soybean yield and leaf and soil Mn concentrations, Perkins Road Agronomy Farm, 1977

				Soil Mn extractant					
Cultivar	Variable	Leaf Mn	Soil Ca	DTPA-TEA	H_2O	Double acid[1]	MAP[2]	H_3PO_4	HCL
		Simple correlation coefficients (r)							
Bragg	Yield	−0.708**	0.826**	−0.607**	−0.526**	−0.663**	0.304	−0.668**	−0.624**
	Leaf Mn		−0.783**	0.703**	0.481**	0.688**	−0.357	0.681**	0.668**
	Soil Ca			−0.747**	−0.561**	−0.808**	0.350	−0.816**	−0.749**
	Soil Mn extractant								
	DTPA-TEA				0.843**	0.969**	−0.305	0.971**	0.958**
	H_2O					0.881**	−0.249	0.878**	0.845**
	Double acid						−0.357	0.997**	0.974**
	MAP							−0.335	−0.383*
	H_3PO_4								0.973**
Lee 74	Yield	−0.069	0.197	−0.238	−0.350	−0.299	−0.137	−0.313	−0.308
	Leaf Mn		−0.577**	0.573**	0.027	0.375*	0.686**	0.374*	0.430*
	Soil Ca			−0.820**	−0.509**	−0.801**	−0.823**	−0.813**	−0.807**
	Soil Mn extractant								
	DTPA-TEA				0.745**	0.930**	0.688**	0.935**	0.948**
	H_2O					0.884**	0.246	0.876**	0.858**
	Double acid						0.637**	0.995**	0.994**
	MAP							0.659**	0.671**
	H_3PO_4								0.993**

[1] 0.05 N HCL + 0.025 N H_2SO_4.

[2] 1.5 M $NH_4H_2PO_4$.

*Significant at the 5% level of probability.

**Significant at the 1% level of probability.

Table 31.—Simple correlation coefficients (r) for soybean yield and leaf and soil Mn concentrations, Perkins Road Agronomy Farm, 1978

Cultivar	Variable	Leaf Mn	Soil Ca	Soil Mn extractant				
				DTPA-TEA	Double acid[1]	MAP[2]	H_3PO_4	HCL
		Simple correlation coefficients (r)						
Bragg	Yield	−0.237	0.139	−0.326	−0.211	−0.230	−0.039	−0.092
	Leaf Mn		−0.578**	0.288	0.115	0.172	0.219	0.067
	Soil Ca			−0.383*	−0.145	−0.046	−0.365*	0.106
	Soil Mn extractant							
	DTPA-TEA				0.700**	−0.230	0.683**	0.681**
	Double acid					−0.118	0.568**	0.659**
	MAP						−0.179	−0.239
	H_3PO_4							0.575**
Lee 74	Yield	−0.103	0.123	0.171	0.255	0.129	0.186	0.051
	Leaf Mn		−0.657**	0.520**	0.155	0.011	−0.192	0.068
	Soil Ca			−0.580**	−0.107	0.289	0.042	−0.194
	Soil Mn extractant							
	DTPA-TEA				0.474**	−0.092	0.432*	0.680**
	Double acid					0.277	−0.386*	0.524**
	MAP						0.133	−0.274
	H_3PO_4							0.584**

[1] 0.05 N HCL + 0.025 N H_2SO_4.

[2] 1.5 M $NH_4H_2PO_4$.

*Significant at the 5% level of probability.

**Significant at the 1% level of probability.

Table 32.—Simple correlation coefficients (r) for soybean yield and leaf and soil Mn concentrations, Perkins Road Agronomy Farm, 1979

				Soil Mn extractant				
Cultivar	Variable	Leaf Mn	Soil Ca	DTPA-TEA	Double acid[1]	MAP[2]	H_3PO_4	HCL
		Simple correlation coefficients (r)						
Bragg	Yield	0.194	0.619**	−0.440*	−0.421*	−0.431*	−0.332	−0.372*
	Leaf Mn		−0.300	0.062	0.023	0.126	−0.077	−0.057
	Soil Ca			−0.461*	−0.497**	−0.425*	−0.313	−0.324
	Soil Mn extractant							
	DTPA-TEA				0.861**	0.725**	0.506**	0.814**
	Double acid					0.782**	0.551**	0.901**
	MAP						0.490**	0.748**
	H_3PO_4							0.570**
Lee 74	Yield	−0.251	0.074	−0.069	−0.252	−0.006	−0.118	−0.213
	Leaf Mn		0.444*	−0.168	−0.121	−0.215	−0.261	−0.067
	Soil Ca			−0.009	−0.202	−0.096	−0.121	−0.063
	Soil Mn extractant							
	DTPA-TEA				0.717**	0.440*	0.877**	0.784**
	Double acid					0.448*	0.880**	0.863**
	MAP						0.570**	0.451*
	H_3PO_4							0.814**

[1] 0.05 N HCL + 0.025 N H_2SO_4.

[2] 1.5 M $NH_4H_2PO_4$.

*Significant at the 5% level of probability.

**Significant at the 1% level of probability.

test values for Mn did not necessarily follow from the higher rates of Mn application.

Factors that may have contributed to the variability of soil test Mn, leaf tissue Mn, and soil-leaf Mn correlation results were: soil type, soil moisture and temperature, and soil sample preparation. Sample preparation may well have more influence than other factors on the ability of soil test interpretations to predict sufficiency or deficiency of Mn for the production of soybeans. Any process that influences the oxidation-reduction potential or pH of the soil is likely to affect Mn solubility, particularly drying the soil prior to analysis.

Summary and Conclusions

An investigation conducted under field conditions determined the influence of soil reaction (applications of S) and five rates of Mn applications on the yield of soybean plants on four Louisiana soils: Norwood silt loam (Typic Udifluvent); Severn very fine sandy loam (Typic Udifluvent); Grenada silt loam (Glossic Fragiudalf), and Falaya silt loam (Aeric Fluvaquent). S applications were made only on the Grenada and Falaya soils. The results of tests in 1977 through 1980 led to the following conclusions:

1. There were no significant positive or negative yield responses to the soil applications of Mn for any soybean cultivar grown on any of the four soils during any year.
2. The yield of Bragg soybeans grown on Falaya silt loam in 1977 was approximately 4 bu/A higher for plots not receiving S (pH 5.5 – 5.8) than for plots receiving S (pH 4.6 – 5.0). Significant yield responses were not observed for the remaining cultivar-year-location combinations.
3. Overall, adjustment of the soil reaction with the addition of S was more reliable in producing changes in leaf tissue Mn and extractable soil Mn than was the soil application of Mn as $MnSO_4 \bullet 3H_2O$, 29 percent Mn.
4. The data show that under conditions of high moisture and low pH (<5.0), Mn concentrations in the loessial soils investigated (Grenada silt loam, and Falaya silt loam) may reach concentrations tending to produce toxic symptoms in the soybean plant and possibly decreasing yields. The Bragg cultivar appeared to be more susceptible than the Forrest or Lee 74 cultivars.

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Control of the Sweetpotato Weevil in Planting Material

L. H. Rolston, T. B. Barlow and E. G. Riley[1]

The crux of the sweetpotato weevil[2] problem in southern Louisiana is control of the weevil in planting material. Most growers produce their own plants to economize and to have an adequate supply of viable plants on hand when they need them. Where the sweet potato weevil is endemic, as it is in many Louisiana parishes where sweet potatoes are grown, precautions should be taken to keep planting material free of infestations.

A plant production program typical among growers begins with certified or foundation sweet potatoes. These are increased the first year, and their progeny provide plants for production fields the second year. The initial stock of certified or foundation sweet potatoes usually goes into farm storage for a few months before bedding. Plants from these sweet potatoes are set in an increase field, and the yield from this field remains in farm storage from harvest in the fall until bedding time the next year. The bedding or "seed" sweet potatoes may become weevil-infested during either storage period.

There are several potential sources of weevil infestation in storage. The storage house may have a residual infestation at harvest from sweet potatoes stored there earlier, and adult weevils may be carried in inadvertently along with sweet potatoes or otherwise gain entrance into the storage house. Also, some of the sweet potatoes may be infested at harvest with immature stages of the weevil. Means of preventing or eliminating infestations from each of these potential sources were investigated in studies conducted at Baton Rouge from 1976 to 1981.

Sweet potato storage houses on farms are normally empty from bedding time in the spring until harvest in the fall, but when the sweet potatoes are removed for bedding a few sweet potatoes and many fibrous roots usually remain. The fibrous roots were of particular concern because it is difficult to clean all of them from a storage house and because it was not known if these fibrous roots would sustain weevils through the summer. One experiment was addressed to this question.

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[2] *Cylas formicarius elegantulus* (Summers). Coleoptera:Cuculionidae. The ESA official common name of this insect is written with sweet potato as one word.

Since adult weevils are quite active, crawling about the walls and floor of an infested storage house as well as among the sweet potatoes, it seemed probable that a residual spray on the interior surfaces of the storage house would be useful as a control measure against adult weevils gaining entrance either through their own efforts or on sweet potatoes or equipment taken into the storage house. The residual spray should also control the smoky brown roach,[3] which may become a nuisance in storage houses, and it should leave no residue on the sweet potatoes. Several insecticides were evaluated as a residual treatment.

Although the use of Imidan as a protective dust applied at harvest has become general practice, its effect on infestations of eggs and larvae already within sweet potatoes at the time of treatment and the persistency of its effectiveness against adult weevils were unknown. Both of these aspects of the treatment are relevant to control of the sweet potato weevil in storage and both were investigated.

Occasionally a grower is short of bedding sweet potatoes because of some mishap or miscalculation. Then he usually buys sweet potatoes for bedding from any available source even though the sweet potatoes are or may be weevil-infested. In such cases weevil control must be focused on the plant beds. Various insecticides were applied at the time of bedding to test their effectiveness as a barrier between infested bedding sweet potatoes and the plants produced by them.

Even though bedding sweet potatoes are uninfested, and plant beds are isolated as far as practicable from potential sources of infestation, some adult weevils may fly into plant beds. Since plant beds occupy a small area relative to the area planted from them, foliar applications of an insecticide to plant beds is a reasonable added precaution against weevil infestation. Several insecticides were tested as foliar applications for their efficacy against adult weevils in plant beds.

A final precaution against transporting weevil eggs and larvae from plant beds to fields is cutting plants rather than pulling them. This practice has long been advocated, but its effectiveness had not been documented.

The objective of the work reported here has been to design a control program which will result in plants that are free of weevils when they are set in the field. Some unpublished work on insecticidal control of the sweet potato weevil and biological studies of this insect contributed to this objective (*1* , *2*).[4]

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[3] *Periplanta fulginosa* (Serville). Orthoptera:Blattidae.

[4] Italic number in parentheses refer to Literature Cited, page 12.

Methods

Survival

Survival of adult weevils in a double walled wooden storage house in July was determined for weevils of unknown age and sex taken from a culture. A total of 130 individuals for each of three treatments were initially divided into lots of 10 individuals. Each lot was confined in a 1-quart, cylindrical, cardboard container the top of which was covered by a double layer of cheese cloth. A sweet potato of the Centennial variety was provided in each container of the control treatment, fibrous roots from sweet potatoes of the same variety were supplied to weevils in the "fibrous root" treatment, and no plant material was available to weevils in the "no food" treatment. Weevils were observed daily for mortality, and temperatures were recorded continuously on a thermograph.

Residues

Strips of unpainted pine measuring about 1 x 6 x .125 inches were dipped into emulsions or suspensions of insecticide, drained of excess liquid, and air-dried. Lower rates of each insecticide were obtained by diluting the highest rate. At 1, 7, 14, 21, and 28 days after treatment, each strip was placed in a 1-quart, cylindrical, cardboard container together with 10 weevils of unknown age and sex from a culture. The container was closed by a double layer of cheese cloth. Mortality was determined a day later, using inability to walk as the criterion for mortality. The experiment contained 10 replications.

Sweet potatoes were tested for acquisition of residue in a malathion-treated storage house. All interior surfaces of a wooden storage house were thoroughly sprayed with .625 pounds of malathion (1 pint of 5EC formulation) in 2½ gallons of spray. The sweet potatoes were placed in storage as soon as the spray dried. Residue samples were taken at each corner and along two walls from crates on the floor, next to the ceiling, and halfway between the floor and ceiling at 1, 3, and 7 days after treatment. Chemical analyses sensitive to .005 ppm were performed under the direction of E. A. Epps, Jr. of the Feed and Fertilizer Laboratory.

Weevil emergence after Imidan treatment

A dip rather than a dust was used in this and the following experiment to assure complete and uniform coverage of the sweet potatoes. To calculate the concentration of Imidan 50W in a dip that would result in a dosage equivalent to 3 ounces of Imidan 5D, an estimate was made of the amount of dip adhering to clean sweet potatoes. This estimate was obtained by noting the reduction in water volume after a known weight of sweet potatoes was dipped in a measured amount of water. The loss averaged 500 ml per 50-pound bushel. Since 3 ounces of Imidan 5D contains 4.253 grams of toxicant, twice this weight of Imidan 50W was added to each 500 ml of water, the amount estimated to adhere to a 50-pound bushel of clean sweet potatoes.

Centennial sweet potatoes used in this experiment were exposed in bulk for 2 days to 10 female weevils per sweet potato. Check samples and samples for treatment were drawn from the bulked lot, the latter at 5-day intervals from the 5th to 35th day after exposure to weevils. The sweet potatoes were held individually at about 85°F until emergence of weevils ceased.

Each treatment was replicated three times, and each replication of a treatment consisted of five sweet potatoes.

Persistance of Imidan treatment

Each of four varieties of sweet potatoes were divided into two lots. One lot of each variety was treated with Imidan as in the previous experiment, and the other lot was left untreated as a check. Both lots were stored at about 65°F. At 12, 66, and 99 days after treatment, a sample of 10 sweet potatoes was taken from each lot of each variety. Each sweet potato was caged separately with 10 weevils of unknown sex that had emerged from a culture within the past 2 weeks. Mortality was observed and punctures counted after a holding period of about 24 hours at about 80°F.

Insecticides applied at bedding

This experiment was conducted out of season, in June, because heavily infested sweet potatoes bedded in early spring rotted in the relatively cool soil and produced no plants. Centennial sweet potatoes were exposed to adult weevils for 3 weeks then treated with a fungicide. These sweet potatoes were laid in furrows over which the treatments were applied in an 18-inch band. Insecticide falling on the sides of the furrows was incorporated into the soil above the sweet potatoes when the sweet potatoes were covered with a disk hiller. As plants began emerging, cages were placed over each plot to prevent movement of weevils among plots. When plants reached a size suitable for setting, a sample of 25 plants was pulled from each cage and the remaining plants were discarded. One additional sample set was taken when plants of suitable size again became available. All samples were examined microscopically for eggs and young larvae.

A randomized complete block design with four replications was employed. Each plot consisted of a single row 10 feet long.

Foliar sprays on plant bed

Insecticides were applied to a plant bed of the Centennial variety after plants had emerged, and again 1 week later, using sprays at the rate of about

100 gallons per acre. On the third and fifth day after each application, 30 weevils of unknown sex were released in each plot. A sample of 10 slips was taken from each plot a week after the last application and examined microscopically for eggs and larvae.

The experimental design was a randomized complete block with six replications. Each plot consisted of a single row 10 feet long.

Cut vs. pulled plants

Six samples of 10 slips each and six samples of 10 cut plants each were taken from untreated plots in a soil insecticide experiment in a plant bed established with heavily infested Centennial sweet potatoes. Paired samples, one of slips and one of cut plants, were taken from each replication. Plants in the samples were examined microscopically for weevil eggs and larvae.

Results

Survival

Without food the most tenacious weevil survived only 5 days at ambient summer temperatures (Table 1). Weevils confined with dry, fibrous sweet potato roots lived no longer than weevils that had no plant material available to them.

Table 1.—Survival of adult sweetpotato weevils provided with sweet potatoes of marketable size (control), fibrous sweet potato roots, and with no food in storage during summer

	Percent survival		
Days	Control	Fibrous roots	No food
1	100	100	100
2	99	87	90
3	97	35	56
4	97	3	12
5	95	1	1
6	92	0	0

Temperatures: min. 72, max. 93; avg. min. 82, avg. max. 89; avg. 86

Residues

Of the six insecticides evaluated for their residual effectiveness when applied to wooden surfaces, both Furadan and malathion killed within a day at least 92 percent of the adult weevils exposed to them. The effectiveness of these residues was undiminished through the 4 weeks of testing

(Table 2). During the exposure period, the weevils had a choice of treated or untreated surfaces upon which to walk or rest. The few weevils surviving exposure to residues of these two insecticides may not have come in contact with the residues.

No malathion was detected by analysis sensitive to .005 ppm in crated sweet potatoes placed in a storage house that had been treated by thoroughly spraying all interior surfaces with .625 pounds of malathion in 2½ gallons of spray.

Table 2.—Percent mortality of adult sweetpotato weevils after one day exposure to residues of various ages on wood.

Treatment		Age of residue (days)				
Insecticide	Rate[1]	1	7	14	21	28
Furadan, 4F	0.5	100	100	100	100	100
	0.25	100	100	100	100	98
Malathion, 5E	6.0	98	97	100	100	99
	3.0	94	100	99	98	96
	1.5	92	98	98	98	98
Mocap, 3E	6.0	100	100	100	84	—
	3.0	100	100	96	86	—
	1.5	100	100	90	70	—
Dyfonate, 4E	4.0	100	100	100	84	—
	2.0	96	88	—	—	—
	1.0	98	78	—	—	—
Imidan, 70W	2.0	86	—	—	—	—
	1.0	68	—	—	—	—
Thiodan, 50W	4.0	66	—	—	—	—
	2.0	48	—	—	—	—
Control	—	0.3	0.6	0	1.8	0.9

[1] Pounds active ingredient per 100 gallons.

Weevil emergence after Imidan treatment

When samples were taken at 5-day intervals from sweet potatoes exposed for 2 days to weevils, and these samples treated with Imidan, large numbers of weevils completed their development and emerged in every sample (Table 3). Only the Imidan treatment applied on the 35th day, when many weevils were enlarging their exit hole, significantly reduced the number of weevils emerging.

Table 3.—Number of adult weevils emerging from 15 sweet potatoes treated with Imidan on indicated day after being infested with eggs.

Day	5	10	15	20	25	30	35
Adults emerged[1]	354	278	426	471	440	329	106

[1] Untreated sweet potatoes produced 485 adult weevils.

Persistance of Imidan treatment

Imidan applied to uninfested sweet potatoes remained highly effective through the 99-day test in killing adult weevils and in reducing the number of punctures (Table 4). Weevils exposed to Imidan-treated potatoes suffered nearly complete mortality within a day, and the number of punctures in the treated potatoes was less than a tenth the number in untreated potatoes during the 1-day exposure period.

Table 4.—Effect of Imidan treated sweet potatoes on mortality and feeding of adult weevils.

Age (days) of Imidan residue	% mortality after 1 day		Number of punctures per weevil after 1 day	
	Imidan	Check	Imidan	Check
12	99.5	2.5	.3	3.6
66	99.5	0	.2	3.6
99	99.8	2.9	.1	2.9

Insecticides applied at bedding

Plants grown from weevil-infested sweet potatoes were protected to a considerable degree by Furadan and by Dasanit banded over the furrow before the sweet potatoes were covered (Table 5). The other insecticides and a low rate of Furadan were much less effective in reducing the number of weevil eggs inserted into the plants. The infestation in plants from untreated plots was very high, amounting to 87 eggs in 100 plants.

Table 5.—Reduction of infestation in plants by banding insecticides over infested sweet potatoes in furrow before covering with soil.

Treatment		Eggs in 100 slips		
Insecticide & formulation	Active ingredient per acre (lbs.)	First pulling	Second pulling	Sum
Furadan, 10G	3	2	1	3
Dasanit, 15G	2.5	2	3	5
Mocap, 10G	3	18	2	20
Dyfonate, 10G	3	14	7	21
Furadan, 10G	1.5	15	7	22
Dyfonate, 10G	1.5	12	12	24
Mocap, 10G	1.5	35	12	47
Thiodan, 50W	1	29	27	56
Check	—	68	19	87

Foliar sprays on plant bed

All of the insecticides tested as foliar applications to a plant bed reduced the incidence of infested plants drastically (Table 6). There was no statistically significant difference among the treatments.

Table 6.—Reduction of weevil infestation in plants by controlling adult weevils in plant bed with weekly applications of insecticide.

Treatment			
Insecticide & formulation	Active Ingredient per acre (lbs.)	Percent plants infested	Number of eggs and larvae in 60 slips
Dyfonate, 4E	1.5	1	2
	.75	0	0
Furadan, 4F	.25	3	5
Imidan, 70W	1.0	3	5
Thimet, 50W	.5	0	0
Check	—	35	42

Cut vs. pulled plants

Cutting plants an inch or more above soil level rather than pulling "draws" or "slips" increased the percentage of weevil-free plants from 38 percent to 98 percent (Table 7). In 60 cut plants, only one egg was present; in 60 pulled plants, the 37 infested plants contained a total of 69 weevil eggs.

Table 7.—Infestation of sweetpotato weevil eggs in 60 slips or cut plants from plant bed established with heavily infested sweet potatoes.

Number of eggs in plant stem	% slips infested	% cut plants infested
0	38	98
1	33	2
2	15	
3	10	
6	2	
7	2	

Conclusion

Infestations of the sweetpotato weevil in planting material can be virtually eliminated by using an appropriate combination of practices.

The risk of infestation in storage is minimized by: (1) storing bedding sweet potatoes in a building reserved for this purpose that has been cleaned soon after sweet potatoes were removed the previous year, (2) treating the interior surfaces of the storage house with malathion, and (3) treating sweet potatoes at harvest with Imidan.

No adult weevil lived more than 5 days without food at ambient summer temperatures in southern Louisiana. Whole potatoes and fragments that serve as food for sweetpotato weevils are easily removed from storage houses. Fibrous roots did not sustain weevils and are of no consequence. Cleaning storage houses soon after sweet potatoes are bedded and leaving them empty through the summer assures freedom from any residual infestation at harvest.

A residual treatment of malathion spray applied to all interior surfaces of a storage house is additional protection from adult weevils that may be carried inadvertently into the storage house along with sweet potatoes or equipment or that may otherwise gain entrance. Although both carbofuran and malathion residues on wooden surfaces destroyed nearly all adult weevils exposed to them and remained effective for at least 4 weeks, malathion is preferable for the safety of the applicator. A rather low dosage of malathion was effective against the weevil, but a rate of .625 pounds of malathion (1 pint of 5EC formulation) is required to control both the weevil and the smokey brown roach. A residual spray applied at this rate to all interior surfaces of a storage house caused no detectable residue in crated sweet potatoes that were placed in storage as soon as the spray dried.

The most important single method of minimizing infestations in storage is the application of Imidan dust to sweet potatoes at harvest. This protectant does not prevent immature weevils which may already be present within sweet potatoes from continuing their development. It does, however, destroy emerging adult weevils before they complete their preoviposition period and start another generation in storage. Additional damage to the stored sweet potatoes is therefore limited to a few inconsequential feeding punctures. The effectiveness of Imidan applied at a rate equivalent to 3 ounces of 5 percent dust per 50-pound bushel was undiminished after 99 days. In practice this is more than sufficient time for all adults to emerge from sweet potatoes that are already infested at harvest.

In the event that weevil-infested sweet potatoes must be used for bedding, plants from these sweet potatoes can be protected to an appreciable degree by an application of Dasanit at the time of bedding. The insecticide is applied in a band that includes not only the sweet potatoes laid in the furrow but also the soil along both sides of the forrow used to cover them. Modification of the application method would be necessary for wide beds. Although Furadan at the rate of 3 pounds per acre is comparable to Dasanit in protection afforded, only Dasanit at a maximum rate of 2.6 pounds per acre in an 18-inch band is approved for this usage. Application of Dasanit at the time of bedding should be reserved for those instances when weevil-infested sweet potatoes must be used for bedding. It should not be a routine practice.

Even though bedding sweet potatoes are uninfested, and plant beds are isolated as far as practicable from potential sources of infestation, some adult weevils may fly into plant beds. The incidence of infestation in plant beds is much reduced by weekly foliar applications of insecticide to the plant bed. Since adult weevils concentrate near the soil surface, a volume of spray sufficient to penetrate the canopy of leaves and wet the plant stems is necessary to assure a high level of control. Although Dyfonate, Furadan, Imidan, and Thimet were equally effective at the rates used, only Thimet at .5 pound of active ingredient per acre is approved as a foliar application on sweet potatoes.

A final precaution should be taken to avoid transferring infestations from the plant bed to increase or production fields. Since nearly all weevil eggs in plant stems are located near the soil surface, cutting plants an inch or more above the soil surface leaves almost all eggs and larvae in the plant bed. In this experiment the percentage of weevil-free plants was increased from 38 to 98 by cutting. Cutting plants also reduces the probability of transferring the reniform nematode[5], root knot nematodes[6], and several soil-borne diseases, especially black rot[7], foot root[8], and scurf[9].

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[5] *Rotylenchulus reniformis* Linford and Oliveria.

[6] *Meliodogyne* spp.

[7] *Ceratocystis fimbriata* Ell. and Halst.

[8] *Plenodomus destruens* Harter.

[9] *Monilochaetes infuscans* Ell. and Halst, ex Harter.

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